LOCATION OF NATURAL DISASTERS SEARCH AND RESCUE (SAR) UNITS IN SECTORS

A THESIS

SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL ENGINEERING

AND THE INSTITUTE OF ENGINEERING AND SCIENCE

OF BILKENT UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

By

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July,2003

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

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ABSTRACT

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M.S. in Industrial Engineering

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July,2003

Disasters are extreme events that cause great loss of life and property and create severe disruption to human activities. After August 17, 1999 Earthquake, Turkish Armed Forces decided to improve its capabilities on specialized search and rescue missions in order to better cope with large scale natural disasters.

After a study conducted at Turkish General Staff Level, it has been decided to form a battalion size search and rescue unit subordinate to special forces command. The battalion is designed to conduct search and rescue perations in cases of flood, earthquake, fire, avalance, chemical and biological disasters.

In this study, in addition to the one Natural Disasters SAR unit in Ankara to serve all the population of Turkey, we aim to locate four new SAR facilities for each sector in an optimum way. Our objective is to maximize the number of people who get served by these new units. Naturally, location of new facilities decreases the travel time or travel distance which is very important in natural disasters missions.

We build the model, named *Basic Model*, for the location of new SAR facilities in each sector. By changing constraints and parameter values of the *Basic Model*, alternative solutions are also presented.

Keywords :Facility Location, Emergency Service, Natural Disasters Search And Rescue

ÖZET

SEKTÖRLERDE DOGAL AFETLER ARAMA VE KURTARMA

BIRLIKLERININ YER SEÇIMI

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Endüstri Mühendisligi Bölümü Yüksek Lisans

Tez Yöneticisi : Assist. Prof. Bahar Y. Kara

Temmuz, 2003

Afetler büyük can ve mal kaybina sebebiyet veren ve insan hayatini felç eden olagan disi olaylardir. 17 Agustos 1999 tarihindeki depremden sonra Türk Silahli Kuvvetleri, büyük çapli dogal afetlerle daha iyi sekilde mücadele etmek için özel arama ve kurtarma görevlerinde kabiliyetlerini gelistirme kararini aldi. Türk Genel Kurmay Baskanliginda yapilan çalismadan sonra Özel Kuvvetler Komutanliginin emir komutasinda tabur seviyesinde arama ve kurtarma birligi olusturulmasina karar verildi. Birlik, deprem, sel, yangin, çig, kimyasal ve biyolojik afetlerle arama ve kurtarma görevlerini icra etmek için planlandi.

Bu çalismada, Türkiye'nin bütün nüfusuna hizmet veren Ankara'daki bir adet dogal afetler arama ve kurtarma birligine ilave olarak, her sektör için dört adet yeni arama ve kurtarma tesisleri optimum sekilde yerlestirmeyi amaçladik. Hedefimiz, bu yeni birlikler tarafindan hizmet verilecek insan sayisini maksimize etmektir. Dogal olarak, yeni tesislerin yerlesimi dogal afetler görevlerinde çok önemli olan ulasim zamanini veya ulasim mesafesini azaltmaktadir.

Her sektör içinde yeni arama ve kurtarma tesislerinin yerlesimi için Temel Model adini verdigimiz modeli olusturduk. Temel Modelin kisitlari ve parametre degerleri degistirilerek alternative sonuçlar da sunulmustur.

Anahtar Kelimeler : Tesis Yeri Seçimi, Acil Servis, Dogal Afetler Arama ve Kurtarma.

To my wife

ACKNOWLEDGEMENT

I am indebted to Asst. Prof. Bahar Y. Kara for her valuable guidance, encourament and above all for the enthusiasm which she inspired on me during this thesis.

I am also indebted to Assoc. Prof. Osman Oguz and Asst. Prof. Oya Ekin Karasan for showing keen interest to the subject matter and accepting to read and review this thesis.

I also want to express my special thanks for Colonel Assoc. Prof. A.Kadir VAROGLU for his increadible endeaver and never-ending motivation in such an honorable way to provide Turkish officers a new horizon. I am grateful to heroic Turkish Land Forces Command for offering me such an opportunity to study in industrial engineering grauate program.

Finally, I wish to thank my wife, my mother, my father, my sister for their patience, endurance, and support throughout this study.

CONTENTS

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Chapter 1

INTRODUCTION

Disasters are extreme events that cause great loss of life and property and create severe disruption to human activities. They can be created by human actions, e.g. transport accidents and industrial explosions or natural processes, e.g. earthquake and flood.

Turkey is affected by many natural and man-made hazards especially by eartquakes, which have caused great losses. Recent examples are earthquakes in Erzincan 1992 and Dinar 1995, the 1995 Senirkent flood and finally much stronger earthqukes at Kocaeli and then Düzce and Bingöl 2003.

After August 17, 1999 Earthquake, Turkish Armed Forces decided to improve its capabilities on specialized search and rescue missions in order to better cope with large scale natural disasters. After a study conducted at Turkish General Staff Level, it has been decided to form a battalion size search and rescue unit located in Ankara subordinate to Special Forces Command. The battalion is designed to conduct search and rescue operations in cases of earthquake, flood, fire, avalance, chemical and biological disasters.

In this study, in addition to the one Natural Disasters SAR unit in Ankara to serve all the population of Turkey, we aim to locate four new SAR facilities for each sector in an optimum way. Our objective is to maximize the number of people who get served by these new units. Naturally, location of new facilities decreases the travel time or travel distance which is very important in natural disasters missions.

Chapter 2 consists of the disaster definition, natural disaster profile of Turkey and finally search and rescue organizations and units present in Turkey.
In this chapter, we state the definition of the disaster shortly and present the natural disaster history of the country. We also compare Turkey with disaster prone countries in three categories : The number of disasters, disaster deaths and disaster damages per event. We present current situations in natural disaster missions of Turkish Armed Forces, Non government organizations and Civil Defence SAR units in Turkey.We We finally state Destructive Earthquakes in Turkey since 1902 and provide the Earthquake Map of Turkey in this chapter.

After some research on our problem, we have found that the structure of the problem is similar to location problems. In Chapter 3, we present facility location problem and related literature.This chapter covers facility location problem definition p-center problem, p-median problem, covering problem,uncapacitated facility location problem, and application areas of different location models. We introduce location papers that largely inspire the work of the thesis in this chapter.

We present the constructions of models in Chapter 4. We firstly state sectors, candidate provinces, demand cities and how these candidate places are chosen in the Problem Definition Section. We also give information about different kinds of SAR units.Finally,all the provinces in sectors are evaluated based on the number of disaster occurances and on the number of disaster related deaths in the Problem Definition Section. We also state how we contruct our model in the Model Definition Section. By changing the parameter values and constraints of the *Basic Model*, we build alternative models besides the *Basic Model*. These are *3 Facility Model* and *Road Must Model* for alternative locations. The constructions of these models are given in Chapter 4.

The computational results are presented in Chapter 5. All four sectors are analyzed and alternative options are presented by changing the parameter values of the *Basic Model*.

In Chapter 6, we give a summary of our research and conclude the study along with suggestions for future research directions.

Chapter 2

NATURAL DISASTERS SEARCH AND RESCUE (SAR) UNITS IN THE TURKISH ARMED FORCES

2.1 What is a Disaster ?

Disaster is a serious disruption of the functioning of a society,causing widespread human, material or environmental losses, which exceed the ability of the affected society (or community) to cope using its own resources. Disasters are often classified according to their speed of onset (slow or sudden) or according to their cause (natural man-made or complex).

Disasters may take many forms and occur as a result of one or more wide range events, both natural and man induced. The duration of these events may range from a few seconds to many years.The severity of the effects of a disaster may vary according to the degree of the damage to human beings and to the environment.

2.2 Natural Disaster History of Turkey

Disasters are extreme events that cause great loss of life and / or property and create severe disruption to human activies. Although Turkey is at risk from a wide variety of natural hazards, including droughts, landslides, forest fires, avalances, floods, blizzards, and earthquakes,we generally associate disaster with earthquake.This is because, geological, topographical, seismic and climatic characteristics of Turkey have caused about two-thirds of all destroyed human construction units and most of the human and animal casulties.

Disasters are integral parts of our human history. As can be seen from the Table 2-1, the placement of Turkey has moved towards a worse direction amoung other countries.

DISASTERS		**DISASTER DEATHS**		**DISASTER DAMAGE '000 US $**	
INDIA	199	FORMER USSR	284334	ITALY	611694
PHILIPPINES	134	CHINA	80812	SPAIN	374686
INDONESIA	110	INDIA	44379	CHILE	121505
BANGLADESH	106	BANGLADESH	26379	FORMER USSR	90645
JAPAN	91	ETHIOPIA	16138	MEXICO	80563
CHINA	89	ITALY	2949	COLOMBIA	51969
BRAZIL	68	PAKISTAN	2061	PAKISTAN	39370
MEXICO	60	JAPAN	2005	CHINA	39296
IRAN	53	CHILE	1107	INDIA	31940
TURKEY	**43**	IRAN	1103	JAPAN	30416
COLOMBIA	39	**TURKEY**	**1027**	BANGLADESH	26831
ITALY	39	COLOMBIA	705	PHILIPPINES	13393
CHILE	37	MEXICO	287	**TURKEY**	**10320**
PAKISTAN	33	INDONESIA	225	BRAZIL	6964
USSR	31	PHILIPPINES	222	INDONESIA	6838
ETHIOPIA	25	SPAIN	106	ETHIOPIA	3129
S. AFRICA	25	BRAZIL	99	IRAN	1415
SPAIN	25	S. AFRICA	73	S. AFRICA	40

Table 2-1: Number of Disasters, Average Disaster Related Deaths and Damages per Event, Ranked Separatedly for Selected Countries, 1900 -1988.

Table 2-1 shows the place of Turkey in three categories of disaster statistics among other significantly disaster prone countries.

Turkey is affected by many natural and man made hazards, especially by earthquakes, which have caused great losses. Recent examples are earthqukes in Erzincan 1992 and Dinar 1995, the 1995 Senirkent landslide and finally much stronger earthquake at Kocaeli and then Düzce in 1999 and Bingöl in 2003. Natural Disaster Profile of Turkey, Destructive Earthquakes in Turkey and Earthquake Map of Turkey are presented at Appendix 1, Appendix 2 and Appendix 3 respectively. [50], [51], [52].

2.3 SAR Organizations and Units in Turkey

Turkish Armed Forces (TAF) is one of the most organized, rooted and reliable institutions of Turkish Republic.The first mission of TAF is to defend Turkish borders against external powers and maintain public order against internal powers. This mission was stated in the first article of Internal Service Law, code no.211, which has been enacted on 4^{th} January 1961. Additional missions of TAF are stated in the 7^{th} and 8^{th} article of " *the law concerning with the measures to be taken and relief to be made because of disasters effecting the general life* " Code no. 7269. Any kind of military units, gendarme military institution commanders are obliged to make aids, when requested by civil authority such as governors or head officials of a district in the peacetime.

On the other hand, TAF has been playing a major role in disaster cases.Especially in the phases of reaction-responce and recovery, TAF always has become the biggest executive power of the disaster management committees and also been deployed as a part of decision, management and labor function in disasters. TAF serves Turkish Nation in all destructive natural disasters. These services can be listed as:

1. Search and rescue,
2. Fire extinguishing,
3. Medical first aid,
4. Transfer of patients and injured people to hospitals,

5. Taking precautions of quarantine,
6. Burial activities,
7. Repair and reservation of electricity, water and sewage sytems,
8. Communication,
9. Transportation,
10. Shelter,
11. Feeding,
12. Removing of ruins and cleaning,
13. Social services.

After August 17, 1999 Earthquake, Turkish Armed Forces decided to improve its capabilities on specialized search and rescue missions in order to better cope with large scale natural disasters. After a study conducted at Turkish General Staff Level, it has been decided to form a battalion size search and rescue unit located in Ankara subordinate to Special Forces Command. The battalion is designed to conduct search and rescue operations in cases of earthquake, flood, big fire, avalance, chemical and biological disasters. The SAR Unit is a joint unit which is composed of professionel soldiers of army, navy, air force. The requirements of a natural disasters SAR team are : [53]

? should deploy in 3 hours within Turkey.

? conduct specialized search and rescue activities at different sites simultaneously.

? establish emergency communications between disaster sites and joint operation center at Turkish General Staff, providing emergency communications support to local civilian authorities and military units if they lose their communications capabilities.

? carry out first aid and emergency medicare up to 39 – 100 victims and aerial medical evacuation.

? operate up to 15 days without resupply.

? provide training support for military units and civilian agencies dealing with disaster relief.

As soon as a crisis arises, immediate responce is to propel the commodity, personnel and vehicles to the Forward Operation Zones (FOZ).
These units are called *Urgent Intervention Units* which are *operation ready* within a maximum of 3 hours. One of the main *Urgent Intervention Units* is the Natural Disasters SAR unit in Ankara. FOZ are planned by the Security, Repose and Assistance Plans (SRAP) in peace times.
If it is needed, TAF will immediately propel the *Second Level Units*, which can be *operation ready* within 6 hours with their material, personnel and vehicles to disasters sites after *Urgent Intervention Units*. The destination locations of these units are pre-planned by the command or the locations, which have been already planned by the Natural Disaster Plan in accordance with Security, Repose and Assistance Plan (SRAP).
There are also units, which are called as *Third Level Units, operation ready* within 12 - 24 hours waiting for the orders to be on board.

On the other hand, contributions of the other governmental organizations like Civil Defence SAR Units and of the non-governmental organizations, AKUT for instance, to search and rescue operations in natural disasters are significant in addition to TAF.

In the light of the experience gained from the 1983 Erzurum, the 1992 Erzincan earthquakes and the former disasters, the Civil Defence General Directorate decided to establish professional Rescue Team in these areas. So, the surplus soldiers and officers of the Civil Defence Organizations were replaced by the professional SAR teams, in Ankara, Istanbul and Erzurum. Following the 1999 Marmara and Düzce Earthquakes, the Civil Defence General Directorate has established eight civil defence search and rescue units, each of which consists of 110 or 120 personnel and various equipment in 8 provinces.

These provinces are : Adana, Afyon, Bursa, Diyarbakir, Izmir, Sakarya, Samsun and Van. Duties of the Civil Defence Search and Rescue Units are : [55]

? To fullfill search and rescue, first aid and social relief services during natural disasters.

? To measure the Nuclear Biological Chemical substances and to convey it to the related authorities.

? To coordinate search and rescue activities of both foreign and local search and rescue teams during a disaster.

? To train search and rescue teams of non-governmental organizations.

? To participate in training and exercise of the search and rescue missions organized both in the country and abroad.

? To perform communication, gathering and mobilisation exercises in order to reach a disaster area rapidly when necessary. Activities carried out by Civil Defence and activities of the Civil Defence Units in the Marmara and Düzce Earthquakes are presented in Appendix 4 and in Appendix 5.

In this study, we have not considered the effects of Civil Defence activities. We aim to find the optimum location nodes for new SAR teams which have capabilities and responsibilities within their sectors in natural disaster operations.

Chapter 3

THE LITERATURE REVIEW

Facility Location Problem is an important research area in industrial engineering and in operations research that encompasses a wide range of problems such as the location of emergency services, location of plants, warehouses, schools, hospitals, location of ATM bank machines, problems in telecommunication networks design, etc. Since the costs incurred to establish new facilities are significantly high, it has become very important for the decision makers to open the facilities in an optimal way.

Given a set of facility locations and a set of customers who are to be served by one or more of these facilities, the general facility location problem is to determine which facilities should be opened so as to minimize the total cost of serving all the customers.

Location Theory was first formally introduced by Alfred Weber [1] in 1909. Alfred Weber considered the problem of locating a single warehouse to minimize the total travel or distance between the warehouse and a set of distributed customers. This work was presented by Isard [2] with the study of land use, industrial location and related problems.

In the 1960's, separate applications of location theory were studied ; fire fighting vehicles by Valinsky [3], a classification yard in a rail network by Mansfield and Wein [4], solid waste disposal sites by Wersan, Quan and Charnes [5], exchange locations in a telephone network by Rapp [6], and factory sites by Burstall, Leavar and Sussans [7].

Location problems were sparked by Hakimi [8] who considered the general problem of locating facility or facilities on a network to minimize either the sum of distances or the maximum distance between facilities and points on a network [10]. Location theory has been an active area of research for the last 20 years.

We present four main location problems in detail [28] :

1. *p*-median problem
2. *p*-center problem
3. Covering Problem
4. Uncapacitated Facility Location Problem

3.1 *p*-median Problem :

The *p*-median problem arises naturally in locating plants and warehouses to serve other plants and warehouses. In the *p*-median problem, we are interested in finding the location of facilities to serve demand nodes so that the travel distance is minimized.

The *p*-median problem is motivated by ReVelle, Marks and Liebman [20] as an example of a public sector location model. Hakimi [10] appears to be the first to define an absolute median. Kariv and Hakimi [22] showed that the *p*-median problem on a general network is NP hard. Interested reader could refer to Tansel, Francis and Lowe [11].

For general networks, a number of solution procedures have been developed recently all based on the vertex-optimality result. Their common characteristic is that they all confine the search to vertex locations. The solution procedures are based on mathematical programming relaxation and branch-and-bound techniques.
In recent papers, Fisher [23] and Maurides [24] discuss new methods for solving the plant location problem.

3.2 *p*-center problem :

The *p*-center problem consists of locating at most p facilities and assigning n customers each to its closest open facility in order to minimize the radius, i.e., the maximum distance between a customer and its closest facility. Many applications of this arise in the public sector as for example; locating fire stations or ambulance depots. The *p*-center problem was formulated by Hakimi [9]. Subsequently, a number of solution procedures have been suggested. A comprehensive survey by Tansel, Francis and Lowe [11] provided a review of *p*-center problems and location problems on tree networks, describing algorithms and solution results.

Kariv and Hakimi [12] showed that the *p*-center problem on a general network is NP hard. Minieka [13] considered a continous *p*-center problem on a general network, assuming all points on each edge must be served by a single center. The vertex restricted *p*-center problem is considered by Toregas, Swain, ReVelle and Bergman [15]. A solution procedure is given which relies on solving a sequence of set covering problems, each corresponding to a specified radius r.

A recent paper by Halpern and Maiman [16] suggests a comparative framework for analyzing *p*-center algorithms given in Tansel, Francis and Lowe [11], Christofides [17], Christofides and Viola [18], Handler [19], Kariv and Hakimi [12] and Minieka [14] and shows how these algorithms fit into the framework.

3.3 Covering Problem :

The objective of the covering problem is to locate a minimum number of servers on a network so that every demand point is within a specified distance of the nearest point. The problem was originally introduced by Church and ReVelle [27] where search for the optimal solution is restricted to nodes. Elzinga and Hearn [25], and Moon and Chaudry [26] seek to locate a fixed number of servers to maximize the number of the nearest server in the maximal covering problem. The problem on the plane was considered by Drezner [30] and by Watson-Gandy [31].

The relationship between the maximal covering problem and the partial center problem is studied in Berman [32]. A more general class of covering problems of which maximal covering location problem is a special case are studied in Kolen and Tamir [33], and Meggido, Zemel and Hakimi [29]. Daskin [35] has extended the problem to allow for the case when the servers are not always available to reply at once. The hiearchical covering problem is presented by Moore and ReVelle [36].

3.4 Uncapacitated Facility Location Problem :

The problem is to find the number and location of the facilities to be operated, as well as the allocation of customers to facilities, in order to minimize the total costs. Formally the uncapacitated facility location problem (UFLP) can expressed as a mixed-integer linear problem. UFLP was originally formulated by Balinsky [37]. Kuehn and Hamburger [38], Manne [39], Stollsteimer [40], and Krarup and Pruzan [41] added to the literature on uncapacitated faciliy location problems.

3.5 Application Areas of Different Location Models :

1. Private Sector Application Areas

a. Warehouses / Production Center Location
b. Factory Work Center Location
c. Communication Network Design / Exchange Location
d. Electric Power Stations
e. Private Service Vehicles (e.g., Taxicab Fleets, Bloodmobiles)
f. Private Service Equipment (e.g.,Oil Spill Cleanup, Cotton Gins, Lock Boxes).
g. Private Service Center Location (e.g.,Tax Collection Office)
h. Transportation Centers (e.g., Shipping Ports, Railroad Classification Yards, Bus Garages)
i. Obnoxious Facilities (e.g.,Toxic Dump, Nuclear Power Plant)
j. Bank Accounts

2. Public Sector Application Areas :

a. Emergency Service Vehicles / Facilities
b. Public Service Centers (e.g., Health Centers, Blood Banks, Waste Treatment Plants)
c. Public Network Design (e.g., Water Treatment Networks)
d. Residential Neighborhoods
e. Defense Installations

The work in this thesis was largely inspired by the works of Toregas, Swain, ReVelle, and Bergman [15], Berman and Krass [42], Rahman and Smith [43], ReVelle and Hogan [21], Schiling, Elzinga, Cohan, Church and ReVelle [44], Marianov and ReVelle [45], Gendreau, Laporte and Semet [46], Jayaraman and Srivastava [47], Adenso- diaz and Rodriquez [48], Church, Stoms and Davis [49] and finally Church and ReVelle [27].

C. Toregas, R. Swain, C. ReVelle, and L. Bergman [15] state the location of emergency facilities as a set covering problem with equal costs in the objective. They seek to position the least number of servers such that all points of demand have at least one server placed within a time of travel or distance standart. In the model in this study, in order to cover all the people living in the sectors, we try to locate minimum number of new SAR facilities in the sectors.

R. Church and C. ReVelle [27] present the maximal covering location problem that aims to seek the placement of a fixed number of facilities in a pattern which maximizes the population within the time of travel or distance standart. In this case, it is assumed that the given number of facilities, limited by financial issues, is insufficient to cover all demand areas within the time or distance standard. *The Basic Model* that we propose is related to their work.

Moreover, C. ReVelle and K. Hogan [21] state the maximum availability location problem, in which the deployment of servers to maximize the population that has service available within a desired travel time with a stated reliability. They introduce randomness in server availability only, travel time is still treated as deterministic.

V. Marianov and C. ReVelle [45], and Schiling, et al. [44] have presented several types of maximal covering problem, the most general one is that known as the FLEET model (for facility, location, equipment emplacement technique). The FLEET model seeks the locations of a limited number of engine companies and truck companies as well as the fire stations that housed them. The goal of the FLEET model is coverage of the maximum number of people by both an engine company sited within an engine company distance standard and a truck company sited within the truck company distance standard. Schiling, et al. [44] develop TEAM (The tandem equipment allocation model). They assume that predetermined numbers of primary and specialty equipment are to be located that a demand node is covered only if it has both primary and speciality equipment within the given standards and that speciality equipment can only be located in tandem (i.e, after) primary equipment.

The 3 Facility Model that we propose is based on the FLEET model in which *Road Earthquake Equipment, Road Flood Equipment* and *Helicopter Equipment* can be located in the different facilities. *The Road Must Model* that we propose is similar to TEAM where specialty equipment can only be located after primary equipment in TEAM and helicopter equipment must be covered after road earthquake and road flood equipment by the demand counties in the *Road Must Model*.

O. Berman and D.Krass [42] introduce the generation of the maximal covering locating problem model. They assume that the coverage level is a decreasing step function of the distance to the closest facility. They also show that generalized maximal covering problem is equavalent to the uncapacitated facility location problem.

R. L. Church, D. M Stoms and F. W. Davis [49] utilize maximal covering location problem for specific problems such as reserve selection and S. U. Rahman and D. K. Smith [43] consider deployment of rural health facilities in a developing country location problem. In reserve selection, they present a form of the maximal covering location model to identify sets of sites which represent the maximum possible representation of specific species. In deployment of health facilities, the case is investigated as the specific problem in developing countries in an optimum way to provide health care for the population.

For emergency facilities, M. Gendreau, G. Laporte and F. Semet [46] consider a double coverage for ambulance location problem. Tabu search heuristic is developed for the solution. V. Jayaraman and R. Srivastava [47] offer a multiple level expected coverage model that seeks to find the location of the number of facilities and the model aims to get number of different equipment on a network such that the amount of demand for the different types of equipment within the service distance is maximized. This model has been formulated for the deployment of various services under conditions of expected unavailability of differing types of equipment. Such services include protection against theft, assault and accidents in the case of police facilities, minimization of losses resulting from fire, loss of lives and properties in the case of location of fire departments and the critical need to transport accident victims to appropriate health care facilities in the case of location of ambulance services.

Finally, B. Adenso-diaz and F. Rodriquez [48] present a simple search heuristic for the maximal covering location problem to design emergency systems which quarantee a certain cover while minimizing determined costs.

Chapter 4

CONSTRUCTION OF MODELS

4.1 Problem Definition

Emergency Services in natural disaster missions depend on the number and capabilities of SAR units and organizations in the country. After Marmara Earthquakes in Turkey, as a disaster prone country, number of SAR units had to be increased to four to serve more people and to decrease the travel time or travel distance between disaster zone and SAR facilities. In our problem, we aim to locate four new SAR units in each sector, in addition to one SAR facility located in Ankara for all natural disasters operations in the country. Althought we are at the risk of all kinds of disasters, earthquake is the most destructive one in all kinds of natural disasters. As a result, one SAR unit can not deal with all natural disasters in the country effectively.

We aim to locate four new SAR units for each sector. There are four sectors in Turkey. The number of counties, and the number and names of candidate places for each sector are shown in the Table 4-1.

Sector Name	Number of Counties	Number of Candidate Cities	Candidate Cities
1st Sector	120	11	Balikesir, Bursa, Çanakkale, Edirne, Istanbul, Kirklareli, Kocaeli, Kütahya, Sakarya, Tekirdag, Yalova
2nd Sector	128	9	Adana, Diyarbakir, Gaziantep, Hatay, Maras, Mardin, Malatya, Mersin, Urfa
3rd Sector	167	5	Elazig, Erzurum, Erzincan, Trabzon,Van
4th Sector	193	4	Antalya, Izmir, Konya, Manisa

Table 4-1:The number of counties and the number of candidate places for each sector.

The candidate places are chosen based on the criteria that at least a brigade level military unit has to be present in these provinces.These candidate provinces are main and important places of the sectors.

1st Sector covers north west of the country whose population is 17.6 million, nearly % 25 of the total population of the country. [56] 2nd Sector consists of north and north east provinces of Turkey. 3rd Sector covers east provinces of the country. The candidate nodes are limited to 5, because the population in this sector is very low and main cities which are evaluated based on the criteria explained above are restricted to 5 in 3rd Sector. Finally, 4th Sector covers west and center cities of the country.

All the provinces are evaluated as the first priority and second priority based on the data, which are the numbers of disasters and the numbers of casualties in natural disasters between 1902 - 2002. We have taken two main natural disaster kinds; earthquake and flood. The other disasters such as avalance, big fires and chemical and biological disasters are mainly related to some certain provinces of the sectors. The names of provinces, the first and second priorities of the disasters for each province are given in the Table 4-2. Center Sector represents SAR Unit in Ankara which is responsible of natural disasters operations in the center provinces of the country.

Sectors	Name of The Provinces	First Priority	Second Priority
1	Balikesir	Earthquake	Flood
1	Bilecik	Earthquake	Flood
1	Bursa	Earthquake	Flood
1	Çanakkale	Earthquake	Flood
1	Edirne	Flood	Earthquake
1	Istanbul	Earthquake	Flood
1	Kirklareli	Flood	Earthquake
1	Kocaeli	Earthquake	Flood
1	Kütahya	Earthquake	Flood
1	Sakarya	Earthquake	Flood
1	Tekirdag	Earthquake	Flood
1	Yalova	Earthquake	Flood
2	Adana	Earthquake	Flood
2	Adiyaman	Earthquake	Avalanche
2	Diyarbakir	Earthquake	Avalanche
2	Gaziantep	Flood	Earthquake
2	Hatay	Flood	Earthquake
2	Içel	Flood	Earthquake
2	Kahramanmaras	Earthquake	Avalanche
2	Kilis	Flood	Earthquake
2	Malatya	Flood	Earthquake
2	Mardin	Flood	Earthquake
2	Osmaniye	Earthquake	Flood
2	Sanliurfa	Earthquake	Flood
3	Agri	Earthquake	Flood
3	Ardahan	Earthquake	Flood
3	Artvin	Earthquake	Flood
3	Bayburt	Earthquake	Flood
3	Bingöl	Earthquake	Avalanche
3	Bitlis	Earthquake	Avalanche
3	Elazig	Earthquake	Avalanche
3	Erzincan	Earthquake	Flood
3	Erzurum	Earthquake	Flood
3	Gümüshane	Flood	Earthquake
3	Hakkari	Avalanche	Earthquake
3	Igdir	Earthquake	Flood
3	Kars	Earthquake	Flood
3	Mus	Earthquake	Flood
3	Rize	Flood	Avalanche
3	Siirt	Earthquake	Avalanche
3	Sirnak	Earthquake	Avalanche
3	Trabzon	Flood	Avalanche
3	Tunceli	Earthquake	Avalanche
3	Van	Earthquake	Avalanche
4	Afyon	Earthquake	Flood
4	Mugla	Earthquake	Flood
4	Antalya	Flood	Earthquake
4	Aydin	Earthquake	Flood
4	Burdur	Earthquake	Flood
4	Denizli	Earthquake	Flood
4	Isparta	Earthquake	Flood
4	Izmir	Earthquake	Flood
4	Konya	Flood	Earthquake
4	Manisa	Earthquake	Flood

4	Mugla	Earthquake	Flood
4	Usak	Earthquake	Flood

Sectors	Name of The Provinces	First Priority	Second Priority
Center	Aksaray	Flood	Earthquake
Center	Amasya	Earthquake	Flood
Center	Ankara	Earthquake	Flood
Center	Bartin	Flood	Earthquake
Center	Bolu	Earthquake	Flood
Center	Çankiri	Earthquake	Flood
Center	Çorum	Earthquake	Flood
Center	Düzce	Earthquake	Flood
Center	Eskisehir	Earthquake	Flood
Center	Giresun	Flood	Earthquake
Center	Karabük	Earthquake	Flood
Center	Karaman	Flood	Earthquake
Center	Kastamonu	Earthquake	Flood
Center	Kayseri	Earthquake	Flood
Center	Kirikkale	Earthquake	Flood
Center	Kirsehir	Earthquake	Flood
Center	Nevsehir	Flood	Earthquake
Center	Nigde	Flood	Earthquake
Center	Ordu	Flood	Earthquake
Center	Samsun	Flood	Earthquake
Center	Sinop	Flood	Earthquake
Center	Sivas	Flood	Earthquake
Center	Tokat	Earthquake	Flood
Center	Yozgat	Flood	Earthquake
Center	Zonguldak	Flood	Earthquake

Table 4-2 : The Priorities of Natural Disasters in the Provinces

As can be seen from the Table 4-2, two important natural disaster kinds ; flood and earthquake take priority over others in the provinces. The percentage of the total provinces in which first priority is flood is % 30 and first priority is earthquake is % 70 in Turkey. New SAR units should contain 3 kinds of equipment in natural disasters operations:

These are :

1. Helicopter Equipment,
2. Road Earthquake Equipment,
3. Road Flood Equipment.

Helicopter Equipment: The Helicopter Equipment contains the equipment that is urgent for earthquake and flood disasters. Some examples of this equipment are portable first aid kit, trauma kit, combined first aid kit, monitored search apparatus (search com), global positioning system, concrete cutters, voice dosimeters, thermal camera, rescue rope, projector, lantern, respirator sysytem with bottle, hand radio, internal communication equipment, satellite phone, etc. The coppers in SAR units are S70 Black Hawk (UH-60)s whose average flight speeds are 180 km/h [56].

We are given 1 hour for the maximum travel time limit by means of helicopter in natural disasters.

Road Earthquake Equipment:This kind of equipment is used for earthquakes and is carried by vehicles. Some examples are rubble- debris removing air bags, hydrolic rescue equipment, panther saws, pneumic drill, crane, special rescue vehicle, special first aid vehicle. Average speed of these vehicles are 60 km/h. We are given 3 hours for the maximum travel time limit by means of earthquake rescue trucks.

Road Flood Equipment : This equipment is used for flood disaster and carried by means of vehicles. Road Flood Equipments include personnel locater system, rifle launched rope and hook, first aid kit, portable crane, portable generator, various kind of life vests, scuba diving equipment, zodiac boat, search and rescue mission dog team vehicle etc. The average speed of these vehicles that carry flood road equiment are 90 km/h. We are given 2 hours for the maximum travel time limit by means of flood rescue trucks.

4.2 Model Definition

We have three kinds of SAR equipment in the model. These three kinds of equipment are carried by different transportation vehicles. Helicopter Equipment is carried by the helicopters to the disaster places. These equipments are urgent and small so that helicopters can carry them in a short time. Earthquake and Flood Road Equipments are carried by road vehicles. Road Earthquake Equipments are more heavier and more complex than Flood Road Equipments so that speeds of vehicles that carry Flood Road Equipment are faster than those of vehicles carrying Road Earthquake Equipments.

We build a model, named *Basic Model*, for location of natural disaster SAR facility in a sector. We employ an optimization model to find the location of SAR facility in each sector. We locate all 3 kinds of equipment in the new SAR facility that is to be opened in each sector. Our objective is to maximize the populations of counties that will be served by the new SAR facility. The notion of service is determined as being in 1 hr travel time by coppers and 2 hrs or 3 hrs (depending on the disaster condisered) travel time by trucks.

By changing the parameter values and constraints, we build alternative location models. Because we aim to present alternative nodes in SAR team locations. These are *3 Facility Model* and *Road Must Model. In 3 Facility Model*, these three kinds of equipment may be opened in different facilities so that total number of facilities to be located in a sector may reach up to 3 in the sector. The objective of *3 Facility Model* is to maximize the populations of the counties that are covered by the three kinds of equipment coverages in the sector. *In Road Must Model*, all the populations (counties) in the sector must be served by the facility that contains Road Earthquake Equipment and Road Flood Equipment whereas the Helicopter Equipment coverage is optional. The objective of *Road Must Model* is to minimize the number of facilities that are opened in the sector.

Now, we will analyze each model separately.

4.3 Basic Model

In the first model that we propose, we aim to find the best location for SAR facility so that the total number of people that receive emergency service is maximized. The coverage distances are1 hr for helicopters, 3 hrs for earthquake rescue trucks and 2 hrs for flood rescue trucks

We have three different objectives in the model. We want to get the weighted combinations of helicopter coverage, road flood coverage and road earthquake coverage in the *Basic Model* and *3 Facility Model*.

Formulation of the Basic Model :

a.Indices :

Set of Demand Nodes (Counties) : I =1,2, ..., m

Set of Candidate Facility Locations : J=1,2, ..., n

In Sector 1: m=120 and n=11;

In Sector 2: m=128 and n=9;

In Sector 3: m=167 and n=5;

In Sector 4: m=193 and n=4;

b. Parameters :

a_i : Population in county i.

VH : Weighted value for earthquake and flood disasters by means of helicopter.

VFR : Weighted value for flood disasters by means of road vehicles.

VER : Weighted value for earthquake disasters by means of road vehicles.

w_i^E : Weighted value for earthquake disaster at county i.

w_i^F : Weighted value for flood disaster at county i.

g^{ER} : Maximum travel time limit by means of road vehicles for earthquake disaster.

g^{FR} : Maximum travel time limit by means of road vehicles for flood disaster.

g^{H} : Maximum travel time limit by means of helicopter.

g^{ER} = 3 hrs, g^{FR} = 2hrs, g^{H} =1 hr.

t_{ij}^H : Travel time from candidate province j to demand city i by means of helicopter

t_{ij}^H =distance (i,j) /180 km/h. (Travel time from node i to node j by means of helicopter is divided by average speed of helicopter.)

t_{ij}^{ER} : Travel time from candidate province j to demand city i by means of road vehicles for earthquake disaster at city i. t_{ij}^{ER} =distance (i,j) /60 km/h (Travel time from node i to node j by means of earthquake equipment truck is divided by average speed of earthquake equipment truck.)

t_{ij}^{FR} : Travel time from candidate province j to demand city i by means of road vehicles for flood disaster at city i. t_{ij}^{FR} =distance (i,j) /90 km/h (Travel time from node i to node j by means of flood equipment truck is divided by average speed of flood equipment truck.)

c. Variables :

X_{ij}^{ER} 1 if a node (i) receives road earthquake coverage from facility j ; 0, Otherwise

X_{ij}^{FR} 1 if a node (i) receives road flood coverage from facility j; 0, Otherwise.

X_{ij}^{H} 1 if a node (i) receives helicopter coverage fom facility ; 0, Otherwise

Z_{j}^{ER} 1 if road earthquake equipment is positioned in a facility at node j ; 0, Otherwise

Z_{j}^{FR} 1 if road flood equipment is positioned in a facility at node j ; 0, Otherwise

Z_{j}^{H} 1 if helicopter equipment is positioned in a facility at node j ; 0, Otherwise

Y_{j} 1 if a facility is stationed at j ; 0, Otherwise.

Objective Function :

$$Max...z = \sum_{I}\sum_{J} X_{ij}^{ER} a_i w_i^E VER + \sum_{I}\sum_{J} X_{ij}^{FR} a_i w_i^F VFR + \sum_{I}\sum_{J} X_{ij}^{H} a_i w_i^F VH + \sum_{I}\sum_{J} X_{ij}^{H} a_i w_i^E VH$$

subject to:

$$t_{ij}^{H} X_{ij}^{H} \leq g^{H} Y_j \qquad (1)$$

$$t_{ij}^{ER} X_{ij}^{ER} \leq g^{ER} Y_j \qquad (2)$$

$$t_{ij}^{FR} X_{ij}^{EF} \leq g^{FR} Y_j \qquad (3)$$

$$X_{ij}^{ER} \leq Z_{j}^{ER}, \forall i \in I \quad , \forall j \in J \qquad (4)$$

$$X_{ij}^{FR} \le Z_j^{FR}, \forall i \in I \ \ , \forall j \in J \qquad (5)$$

$$X_{ij}^{H} \le Z_j^{H}, \forall i \in I \ \ , \forall j \in J \qquad (6)$$

$$Z_j^{ER} \le Y_j, \forall j \in J \qquad (7)$$

$$Z_j^{FR} \le Y_j, \forall j \in J \qquad (8)$$

$$Z_j^{H} \le Y_j, \forall j \in J \qquad (9)$$

$$\sum_J Y_j = 1 \qquad (10)$$

$$X_{ij}^{EH}, X_{ij}^{FR}, X_{ij}^{H}, Z_j^{ER}, Z_j^{FR}, Z_j^{H}, Y_j \in \{0,1\}, \forall j \in J, \forall i \in I \qquad (11)$$

d. Constraints :

The objective function is to maximize the weighted combinations of three kinds of coverages: Helicopter coverage, road earthquake coverage and road flood coverage. Constraint (1) states that if i county is covered by helicopter coverage at node j $(X_{ij}^{H} = 1)$, Y$_j$ must be equal to 1 which f orces a facility to be stationed at node j. The first constraint also states that travel time from node j to node i must be less than or equal to maximum travel time by helicopter.

Constraint (2) shows that if county i is served by node at j, then we station a facility at node j, and travel time from node j to node i must be less than or equal to maximum travel time by earthquake rescue trucks. Constraint (3) states that if the county i is covered by node j then a facility is stationed at node j and travel time from node j to i must be less than or equal to maximum travel time by flood rescue vehicles.

Constraint (4) states that if a node (i) is covered by a facility at node j for earthquake by means of road, $(X_{ij}^{ER} = 1)$, then road earthquake equipment is positioned in a facility at node j $(Z_j^{ER} = 1)$ The other 2 constraints (5), (6) are respective constants for road flood and road equipment positionings. Constraint (7) shows that if road earthquake equipment is positioned at node j, $(Z_j^{ER} = 1)$, then we open a facility at node j . $(Y_j = 1)$ The other 2 constraints are in the same form. Constaint (10) ensures that total number of facility that will be opened is equal to 1.

4.4 3 Facility Model :

If we are allowed to locate equipment kinds in alternative places, *3 Facility Model* ensures this property.

In this model, we locate 2 road equipments and 1 helicopter equipment in different facilities , so that total number of facility to be located in a sector may reach to 2 in each sector.The objective of *3 Facility Model* is to maximize the weighted combination of people who are covered by three kinds of equipment coverages in sectors. The different variables and constraints are explained in this section. The remaining parameters, variables, constraints and objective function are the same as the *Basic Model.*

a.Variables:

Y_{ij}^{ER} 1 If a facility for road earthquake equipment is stationed at node j ; 0, Otherwise.

Y_j^{FR} 1 If a facility for road flood equipment is stationed at node j ; 0, Otherwise.

Y_j^H 1 If a facility for helicopter equipment is stationed at node j ; 0, Otherwise.

Formulation of the Model :

Objective Function :

$$Max...z = \sum_I \sum_J X_{ij}^{ER} a_i w_i^E VER + \sum_I \sum_J X_{ij}^{FR} a_i w_i^F VFR + \sum_I \sum_J X_{ij}^{H} a_i w_i^F VH + \sum_I \sum_J X_{ij}^{H} a_i w_i^E VH$$

subject to:

(4), (5), (6)

$$t_{ij}^H X_{ij}^H \le g^H Y_j^H \qquad (12)$$

$$t_{ij}^{ER} X_{ij}^{ER} \le g^{ER} Y_j^{ER} \qquad (13)$$

$$t_{ij}^{FR} X_{ij}^{FR} \le g^{FR} Y_j^{FR} \qquad (14)$$

$$Z_j^{ER} \le Y_j^{ER} \qquad (15)$$

$$Z_j^{FR} \le Y_j^{FR} \qquad (16)$$

$$Z_j^{H} \le Y_j^{H} \qquad (17)$$

$$\sum_j Y_j^{ER} = 1 \qquad (18)$$

$$\sum_j Y_j^{FR} = 1 \qquad (19)$$

$$\sum_j Y_j^{H} = 1 \qquad (20)$$

$$X_{ij}^{ER}, X_{ij}^{H}, X_{ij}^{FR}, Z_j^{H}, Z_j^{FR}, Z_j^{EF}, Y_j^{H}, Y_j^{ER}, Y_j^{FR} \in \{0,1\}, \forall j \in J, \forall i \in I. \qquad (21)$$

b.Constraints :

The objective function is to maximize the weighted combination of people who are covered by three kinds of equipment coverages in sectors. Constraints (12), (13), (14) are the same as in the *Basic Model* except the facility kinds.

Constraint (15) states that if road earthquake equipment is positioned in a facility at node j $(Z_j^{ER} = 1)$, then we open a facility for road earthquake equipment at node j. Constraints (16) and (17) are similar for road flood coverage and helicopter coverage. Constraint (18) ensures that total number of facility which contains road earthquake equipment is equal to 1. Constraint (16) and (17) are similar for flood road and helicopter equipment.

This model gives alternative location nodes in some sectors different from ones in the *Basic Model*. We will explain the differences in the Model Solution Section.We present another model in next section.

4. 5 Road Must Model :

In this model , all the populations (counties) in the sector must be served by the facility that consists of both road earthquake and road flood equipments whereas the helicopter equipment facility coverage is optional.

Our objective is to minimize the number of facilities that are opened in the sector.New facilities contain both road earthquake and road flood equipments. The helicopter coverage and number of facility which c onsists of helicopter equipment are not considered. The indexes, parameters, variables are the same as the *Basic Model*.

Formulation of the Model :

Objective Function :

$$Min......z = \sum_j Y_j$$

subject to :

(2), (3), (4), (5),(7), (8), (11)

$$X_{ij}^{H} \leq X_{ij}^{ER} \qquad (22)$$

$$X_{ij}^{H} \leq X_{ij}^{FR} \qquad (23)$$

$$\sum_j X_{ij}^{ER} \geq 1 \quad \text{for all i} \qquad (24)$$

$$\sum_j X_{ij}^{FR} \geq 1 \quad \text{for all i} \qquad (25)$$

a.Constraints :

The constraints (1), (2), (3), (4), (5), (6), (7), (8), (11) are the same as those and explained in the *Basic Model* section. If a node i is receiving helicopter coverage, then it should also receive road earthquake coverage due to the cover distances. Constraint (22) and (23) ensure this property. Constraints (24) and (25) ensure that each node receives both road flood and road earthquake coverages. We present the applications of three models in finding location nodes for new SAR facilities in Turkey.

Chapter 5

MODEL SOLUTIONS

We coded the model in GAMS and took the computational result reports by Cplex 7.1 running on a server type computer which has 12*400 mhz and 3 G byte memory. The populations of the counties are taken from the book named " Karayolu Agi ". [54] 1 hr, 2 hrs, 3 hrs are given from TAF for helicopter coverage, road flood coverage and road earthquake coverage respectively.

Weighted value for earthquake and flood disasters by means of helicopter (VEH) is taken as 0.5, weighted value for flood disasters by means of road vehicles is taken as 0.3 and finally, weighted value for earthquake disasters by means of road vehicles is taken as 0.2 (Total weighted value is 1). The reason why VEH is half of the total weighted value is that helicopter carriage is vital in emercengy rescue missions in natural disasters. We have also results of the alternative parameter values for VEH, VFR, VER in the models. These values are 0.5 / 0.25 / 0.25, 0.7 / 0.15 / 0.15, 0.8 / 0.1 / 0.1, 0.9 / 0.05 / 0.05 for VEH, VFR and VER respectively. The reason why we used the alternative parameters is that we want to know how these changed parameters affected our solutions.

We have also weighted value for earthquake at node i (w_i^E) and weighted value for flood at node i (w_i^F) .We calculate (w_i^E) by dividing the number of death people in earthquake at node i since 1902 by the total number of death people in earthquake disasters in its sector since 1902. The same procedure is used for weighted value for flood at node i (w_i^F). The data for weighted value for earthquake and weighted value for flood are given in Appendix 6, Appendix 7, Appendix 8, Appendix 9. Our objective is weighted combinations of equipment coverages in the *Basic Model* and *3 Facility Model*. But, weighted objective functions do not make sense. So that we calculate the population of the sectors. We present the results in the following.

5.1 BASIC MODEL

In the *Basic Model*, all three kinds of equipment are located in one facility for the sector. All the populations and counties are served by this new facility. The objective of the *Basic Model* is to maximize the population of sectors that are covered by new facilities. We also report the numbers and percentages of county coverages in terms of both helicopter equipment and road equipment coverages by the new SAR facilities that are opened.

We present the results of one SAR facility location for sectors in Table 5-1.

Sector Name	**Proposed Places**	**Total Population of the Sector**	**Population of Sector Covered by SAR**	**Total # of Counties in Sectors**	**# of Counties That SAR Covers**
Sector 1	Yalova	17610368	16653009 (94.5 %)	120	93 (77.5 %)
Sector 2	Gaziantep	13978998	9785365 (70 %)	128	83 (64.8 %)
Sector 3	Erzurum	6952942	3741024 (53.8 %)	167	94 (56 %)
Sector 4	Izmir	14739675	8682176 (59 %)	193	77 (40 %)

Table 5-1 :Results of one facility location in each sector for the *Basic Model*.

For Sector 1 which serves Marmara region, YALOVA is chosen for the location of the SAR team that covers % 94 of the total population. We can also see that 93 of 120, total number of counties, are served by the facility at city YALOVA.

For the 2nd sector which represents south and south east of the country, GAZIANTEP is selected for SAR facility location place. GAZIANTEP serves % 70 of all population in this region, moreover, 83 of 128 counties are covered by the new SAR facility at node GAZIANTEP. In the 3rd Sector ERZURUM is the most suitable city for SAR facility location in east cities of Turkey. Because of the longer distances between cities and fewer people in provinces, the percentage of the population that is served by the facility in ERZURUM decreases to 53.8. We can report that by this coverage, only 94 of 167, total number of counties in this sector, are covered by this new facility in ERZURUM. In 4th sector, IZMIR is the optimum place in west provinces of Turkey. With % 59 coverage percentage in population, people in this sector could be served by the new SAR facility in IZMIR.

Recall that only one SAR Unit is to be located in this model. Observing the low coverage percentages in sectors, we wanted to analyze the effect of more SAR teams and we increase p from 1 to the number of candidate sites. For sectors 1, and 2, we stop at p=5 since we got 100 % coverages. Table 5-2, Table 5-3, Table 5-4 and Table 5-5 present the results.

As can be seen from the Table 5-2, when p=2 in the 1st Sector, YALOVA and KOCAELI are selected as the optimum places with % 95 coverage percentages in population, so that number of counties are increased from 93 counties to 94 counties. For p=3, YALOVA, KOCAELI and ISTANBUL are chosen with % 99.4 coverage percentage. For p=4, SAKARYA is chosen as the fourth candidate province, but the population coveage has not changed much with % 99.5 percentage. With p=5, all the people in this region are served by the five new SAR facilities.

# of SAR Units	Proposed Places	Total Population of the Sectors	Population of Sector Covered by SAR	Total # of Counties in Sectors	# of Counties That SAR Covers
1	Yalova	17610368	16653009 (94.5 %)	120	93 (77.5 %)
2	Yalova Kocaeli	17610368	16738431 (95 %)	120	94 (78 %)
3	Yalova Kocaeli Istanbul	17610368	17502944 (99.4 %)	120	115 (95.8 %)
4	Yalova Kocaeli Istanbul Sakarya	17610368	17524720 (99.5 %)	120	116 (96.7 %)
5	Yalova Kocaeli Istanbul Sakarya Bursa	17610368	17610368 (100 %)	120	120 (100 %)

Table 5-2 : Results of new SAR facility locations for the1st sector in the *Basic Model*

For the 2nd sector, GAZIANTEP and MARAS provinces serve % 70.3 of all population in this sector. ADANA is selected for the third candidate node in this region with % 80.3 population coverage percentages.

Although we increase the number of facility number from three to four, the population coverage has not changed. With five new SAR facilities in GAZIANTEP, MARAS, ADANA, HATAY and URFA provinces, all the people are covered as can be seen from Table 5-3.

# of SAR Units	Proposed Places	Total Population of the Sectors	Population of Sector Covered by SAR	Total # of Counties in Sectors	# of Counties That SAR Covers
1	Gaziantep	13978998	9785365 (70 %)	128	83 (64,8 %)
2	Gaziantep Maras	13978998	9824590 (70.3 %)	128	85 (66.4 %)
3	Gaziantep Maras Adana	13978998	11219768 (80.3 %)	128	93 (72.7 %)
4	Gaziantep Maras Adana Hatay	13978998	11219768 (80.3 %)	128	93 (72.7 %)
5	Gaziantep Maras Adana Hatay Urfa	13978998	13978998 (100 %)	128	128 (100 %)

Table 5-3: Results of new SAR facility locations for the 2nd Sector in the *Basic Model*.

The results for the 3rd Sector are given in Table 5-4. For p = 2, ERZURUM and VAN have increased the number from to % 53,8 to % 77 coverage percentage in population. By adding ERZINCAN province, the population coverage percentage jumps to % 97.38 from % 77. We can report that the number of counties increases to 159 from 167 total number of counties in this sector. Increasing p to 4 did not change the results. 5 SAR teams of ERZURUM, VAN, ELAZIG, TRABZON and ELAZIG are required to cover all the counties in this sector.

# of SAR Units	Proposed Places	Total Population Of the Sectors	Population of Sector Covered by SAR	Total # of Counties in Sectors	# of Counties That SAR Covers
1	Erzurum	6952942	3741024 (53.8 %)	167	94 (56 %)
2	Erzurum Van	6952942	5365240 (77 %)	167	125 (75 %)
3	Erzurum Van Erzincan	6952942	6771498 (97.38 %)	167	159 (95.21 %)
4	Erzurum Van Erzincan Trabzon	6952942	6771498 (97.38 %)	167	159 (95.21 %)
5	Erzurum Van Erzincan Trabzon Elazig	6952942	6952942 (100 %)	167	167 (100 %)

Table 5-4: Results of new SAR facility locations for the 3th Sector in the *Basic Model*

Table 5-5 provides the results for the 4th, which consists of west and west centeral cities of the country. For p=2, IZMIR and MANISA are chosen as the optimum nodes that serve % 62 of the total population. The percent coverage reaches to % 92.34 for p=3. The best coverage for this sector is %97.34 when we open a SAR team of every candidate location.

# of SAR Units	Proposed Places	Total Population of the Sectors	Population of Sector Covered by SAR	Total # of Counties in Sectors	# of Counties That SAR Covers
1	Izmir	14739675	8682176 (59 %)	193	77 (40 %)
2	Izmir Manisa	14739675	9128439 (62 %)	193	86 (44.6 %)
3	Izmir Manisa Konya	14739675	13611330 (92.34 %)	193	160 (82.9 %)
4	Izmir Manisa Konya Antalya	14739675	14348071 (97.34 %)	193	187 (96.9 %)

Table 5-5: Results of new SAR facility locations for the 4th Sector in the *Basic Model*

We also wanted to analze the effects of the cover radius to the solutions. Thus, we changed the parameters of the *Basic Model* . The changed parameters are :

? Maximum Time Limit for Helicopter Equipment (g^H)
? Maximum Time Limit for Road Earthquake Equipment (g^{ER})
? Maximum Time Limit for Road Flood Equipment (g^{FR})

When we change the parameter values of the *Basic Model*, we get the results in the Table 5-6. BURSA is an alternative province for the 1th Sector. GAZIANTEP and ERZURUM are the same optimum SAR nodes in the *Basic Model*. ANTALYA, MANISA are other candidate provinces for the 4th Sector. When we increase g^H from 1 to 2, all the population of the sectors are covered except the 4th one. In the 4th Sector 99.5 of the total population are served by one new SAR facility. By changing g^{FR} from 2 to 5, the coverage percentages are also increased from % 94.5 to % 99.9 in the 1st Sector, from % 70 to % 97 in the 2nd Sector, from % 53.8 to % 91.6 in the 3th Sector and from % 59 to % 99.7 in the 4th Sector.

When g^{ER} = 4, g^H = 1 and g^{FR} = 5, the coverage percentages are increased between % 91.6 and % 99.5 for the four sectors. With g^{ER} = 3, g^H = 1 and g^{FR} = 4, the percentages of the people who are covered change from % 85.8 to % 98.We can say that 2 hrs travel time by coppers serves all the sectors except the 4th Sector. So, g^H must be bigger than 2 in this sector.When we increased g^{ER} to 4, MANISA is selected for location nodes instead of ANTALYA. Because in the 4th Sector, counties are far from each other.To cover all the population in this sector, g^{ER} must be at least 5 in the 4th Sector. IZMIR is an alternative node for g^{ER} =3, g^H =1 and g^{FR} =4 to serve all the population, g^{FR} must be bigger than 5 hrs.

Sector Name	Required Parameters g^{ER} / g^{H} / g^{FR}	Proposed Places	Population of Sector that SAR Covers	# of Counties that SAR Covers
Sector 1	3 / 2 / 4	Yalova	17610368 (100 %)	120 (100 %)
	3 / 1 / 5	Yalova	17598350 (99.9 %)	119 (99.17 %)
	4 / 1 / 5	Yalova	17370498 (98.6 %)	112 (93.3 %)
	3 / 1 / 4	Yalova	17062289 (97)	106 (88.3 %)
Sector 2	3 / 2 / 4	Gaziantep	13978998 (100 %)	128 (100 %)
	3 / 1 / 5	Gaziantep	13826580 (98.6 %)	124 (96.9 %)
	4 / 1 / 5	Gaziantep	13826580 (98.6 %)	124 (96.9 %)
	3 / 1 / 4	Gaziantep	12736005 (91.10 %)	104 (81.3 %)
Sector 3	3 / 2 / 4	Erzurum	6952942 (100 %)	167 (100 %)
	3 / 1 / 5	Erzurum	6369754 (91.6 %)	154 (92.2 %)
	4 / 1 / 5	Erzurum	6369754 (91.6 %)	154 (92.2 %)
	3 / 1 / 4	Erzurum	6952942 (85.8 %)	140 (83.8 %)
Sector 4	3 / 2 / 4	Antalya	14436612 (97.9 %)	187 (96.4 %)
	3 / 1 / 5	Antalya	14705024 (99.7 %)	191 (98.9 %)
	4 / 1 / 5	Manisa	14666589 (99.5 %)	191 (98.9 %)

	3 / 1 / 4	Izmir	13936837 (94.55 %)	182 (94.3%)

Table 5-6 : Results of one facility location in each sector for the changed parameters of the *Basic Model*

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5.3 FACILITY MODEL

In this model, all three kinds of equipment are allowed to be opened in different candidate places, so that the number of facilities is at most 3 in each sector.

The objective of *3 Facility Model* is to maximize the populations of the counties that are covered by at least one kind of three kind equipment coverages in each sector. We used the same parameters of the *Basic Model* for *3 Facility Model.*

# of SAR Units	**Proposed Places**	**Total Population of the Sectors**	**Population of Sector Covered by SAR**	**Total # of Counties in Sectors**	**# of Counties That SAR Covers**
Sector 1	HE = Bursa ER = Yalova FR = Yalova	17610368	16951536 (96.3 %)	120	101 (84.2 %)
Sector 2	HE=Gaziantep ER=Maras FR=Maras	13978998	9785365 (70 %)	128	83 (64.8 %)
Sector 3	HE=Erzurum ER=Trabzon FR=Trabzon	6952942	4481363 (64.5 %)	167	107 (64.1 %)
Sector 4	HE=Manisa ER=Izmir ER=Izmir	14739675	9694930 (65.8 %)	193	91 (47.2 %)

Helicopter Equipment = HE, Road Earthquake Equipment = ER,

Road Flood Equipment = FR.

Table 5-7 : Results of 3 alternative facility location in each sector.

In the *3 Facility Model*, for the first Sector, BURSA with new helicopter equipment node and YALOVA with road earthquake and road flood equipment are the SAR location nodes. The coverage percentage of population in the 1st Sector is % 96.3. When we compare the *3 Facility Model* to the *Basic Model*, we get the following results as shown in the Table 5-7.

In the 1st Sector,YALOVA and KOCAELI serves %95 of the total population in the *Basic Model*. Coverage percentage is % 96.3 in the *3 Facility Model* when we locate helicopter equipment in BURSA, road earthquake and road flood equipment in YALOVA. The *3 Facility Model* is more effective than one SAR unit in the *Basic Model*. Because for p=2, we must locate 2 times equipment teams than ones in the 3 *Facility Model*. By locating equipment teams in alternative candidate nodes, we increase the coverage percentage without adding new SAR teams.

For the 2nd Sector, the population coverage of two facility location in the *Basic Model* is % 70.3. The coverage percentage is % 70 in *3 Facility Model*, where helicopter equipment is located in ANTEP and road earthquake and road flood equipment are located in MARAS.

In the 3rd Sector, TRABZON and ERZURUM cover % 64.5 and in the 4th Sector, MANISA and IZMIR serve % 65.8 of the total population and this percentage decreases to % 62 in the *Basic Model* .(Table 5-7)

5.3 ROAD MUST MODEL

In this model, all the populations and counties in sectors are covered by the facilities (facility) that consist(s) of road earthquake equipment and road flood equipment. On the other hand, helicopter equipment is optional in covering the counties. The objective of this model is to minimize the number of facility that is to be opened. We used the same parameters used in the *Basic Model* for *Road Must Model*. We coded the model and got the results as shown in Table 5-8.

Sector Name	# of SAR Units That are Opened	Proposed Places	Population of Sectors That SAR's Cover	# of Counties That SAR's Cover
Sector 1	5	Kirkareli Kocaeli Balikesir Çanakkale Yalova	17610368 (100 %)	120 (100 %)
Sector 2	7	Malatya Gaziantep Mersin Maras Adana Hatay Urfa	13978998 (100 %)	128 (100 %)
Sector 3	5	Erzurum Van Erzincan Trabzon Elazig	6952942 (100 %)	167 (100 %)
** Sector 4	4	Izmir Manisa Konya Antalya	14348071 (97.34 %)	187 (96.9 %)

Table 5-8 : Results of *Road Must Model* in each sector.

In order to cover all of the population and the counties, minimum number of facility by both road earthquake and road flood equipment is 5 for 1st, 3rd sectors and 7 units for 2nd Sector. The selected provinces are presented in the Table 5-8.

In order to cover all the populations of 4th Sector, we have to have at least five for the number of candidate facility nodes as shown in the Table 5-8.

In *Road Must Model*, we omit the number of helicopter equipment and facilities containing helicopter equipment .The reason is that there are limited numbers of coppers in SAR teams. SAR Units can not deal all the disasters in the sector by means of helicopter at the same time.

5.4 Proposed Solution :

As a result, YALOVA, GAZIANTEP, ERZURUM, and IZMIR are proposed as the optimum cities for one SAR location that contains all three kinds of equipment in 1st,2nd, 3rd and 4th sectors with % 94.5, % 70, %53.8 and % 59 coverage percentages respectively. If we are allowed to locate the equipments in different places, we can choose BURSA for helicopter equipment and YALOVA for both road earthquake and road flood equipment in the 1st Sector.

GAZIANTEP, ERZURUM, and MANISA are the suitable location provinces for helicopter equipment in the 2nd, 3rd and 4th sectors whereas MARAS, TRABZON, and IZMIR are selected for road earthquake and road flood equipment in the 2nd, 3rd and 4th sectors respectively. In the *3 Facility Model*, the coverage percentages are % 96.3, % 70, % 64.5 and % 65.8 for 1st, 2nd, 3rd, 4th sectors.

Consequently, *3 Facility Model* gives TAF to cover more people with few equipment teams. Four new SAR units in these sectors serve % 73 population of total population coverage in the four sectors. We can report that 347 of 608 total counties in four sectors are covered with % 57 coverage percentage.

chapter 6

CONCLUSIONS

6.1 CONCLUSION :

In this thesis, three kinds of models for facility location are used to maximize the size of the population served by SAR units in the sectors.

Instead of one SAR unit located in ANKARA, 4 new SAR units for each sector will be much more effective in natural disasters search and rescue operations in Turkey.

We should state that we get robust solutions for the 1st, 2nd and 3rd sectors. Although we change the parameter values in the *Basic Model*, we get the same nodes ; YALOVA in the 1st sector, GAZIANTEP in the 2nd sector and ERZURUM in the 3rd sector.

We see that CPU is very short for all the models. These models can be used for increased number of facilities and increased number of demand nodes effectively in a short time. But TAF wants to get these numbers of facilities.

As a result, it will be beneficial to use these facility location models to choose the optimum nodes. The number of facilities can be increased or decreased, but it would be better to adjust the facility location of SAR units for the Turkish Armed Forces.

6.2 FUTURE RESEARCH DIRECTIONS :

We have only one SAR unit located in ANKARA for the whole population of Turkey. It is obvious that more SAR units which are located in the selected cities are more beneficial than the current condition. Although all the facilities and equipment are related to financial issues, Turkish Armed Forces have to be ready for all kinds of natural disasters especially earthquakes.

As a future research :

? We have used 3 kinds of equipment in the models : Road Earthquake Equipment Helicopter Equipment, Road Flood Equipment. Equipment kinds can be identifed as primary equipment and secondary equipment as a future research topic.

? Ou analysis covers 53 million people in total in the four sectors of the country. All counties in Turkey can be analyzed totally not based on four sectors for new SAR facility locations.

We mean that p is equal to 4, and demand nodes are all the counties of the country and candidate nodes are chosen among the country cities not in the sector cities.

? As a further research avenue, the weighted parameter values may contain injured and damaged properties not only deaths in the natural disasters. So that much more detailed study can be found in SAR facility locations.

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APPENDIX

APPENDIX 1 Natural Disaster Profile of Turkey

Type	Year	Month	Day	Killed	Injured	Location
Earthquake	1903	4	29	6000		Malazgirt
Earthquake	1912	8	9	923	1575	Murefte, Sarköy
Earthquake	1914	10	3			Isparta
Earthquake	1928	3	30	50	209	Torbali
Earthquake	1935	1	4	5	30	Erdek
Earthquake	1938	4	19	149	800	Kirsehir
Earthquake	1939	11	21	43		
Earthquake	1939	12	6	32962		Erzincan
Earthquake	1940	2	20	37		Erciyes, Develi
Earthquake	1942	11	15	7		Bigadiç
Earthquake	1942	12	20	3000		Niksar
Earthquake	1943	11	26	2824	5000	Ladik
Earthquake	1944	2	1	3959		Gerede
Earthquake	1944	10	6	27		Ayvalik
Earthquake	1946	5	31	839		Eastern Turkey
Flood	1948	2		200		
Flood	6			132		
Earthquake	1949	7	23	2		Karaburun
Earthquake	1949	8	17	450		Karliova
Earthquake	1951	8	13	52		Kursunlu
Earthquake	1952	10	22	10		Adana
Earthquake	1952	1	3	133		Erzurum
Earthquake	1953	3	18	265		Nortwest of Turkey
Flood	1956	8	138			
Earthquake	1957	4	25	67		Fethiye
Earthquake	1957	5	26	52		Bolu
Flood	1957	9		99		
Flood	1964	3	10			
Earthquake	1964	10	6	23	100	Bursa
Earthquake	1966	7	3	14		Mus
Earthquake	1966	8	19	2394	1500	Varto
Earthquake	1967	7	22	89	360	W.Turkey
Earthquake	1968	9	3	29		Bartin
Flood	1968	12	28	147		
Earthquake	1969	3	28	41	350	Alasehir
Earthquake	1970	3	28	1086	2776	Gediz
Earthquake	1971	5	2	57		Burdur
Earthquake	1971	5	22	878	1200	Bingöl
Flood	1974	11	19	33		

Earthquake	1975	9	6	2385	3372	Lice

APPENDIX 1 Natural Disaster Profile of Turkey Continued

Type	Year	Month	Day	Killed	Injured	Location
Earthquake	1976	11	24	3840	15000	Muradiye
Slide	1976	9	12	40		Ordu
Slide	1976	2		27		
Earthquake	1976	8	19	4	28	Denizli
Earthquake	1977	3	26	8		Elazig
Flood	1980	3		75		
Slide	1980	3	27	40		Kayseri
Flood	1981	12	17	10		W.Turkey
Earthquake	1983	10	30	1155	1142	Erzurum
Earthquake	1984	9	18	3	35	Erzurum
Earthquake	1986	5	5	13	100	Malatya
Slide	1988	6	23	64	130	Trabzon
Flood	1988	6	13	13		Ankara
Slide	1992	1	2	20	15	Hakkari
Slide	1992	1	20	10		Siirt
Slide	1992	2	1	261	69	Sirnak
Earthquake	1992	3	13	547	2000	Erzincan
Slide	1993	1	18	135		Özengeli
Flood	1995	5	2		1	Bitlis
Flood	1995	7	10	70	30	Ankara, Senirkent
Earthquake	1995	10	1	101	348	Dinar
Flood	1995	11	4	78	60	Izmir
Flood	1998	5	21	16		Zonguldak
Flood	1998	6	12	22		Diyarbakir
Earthquake	1998	6	28	145	1517	Ceyhan
Earthquake	1998	7	4		1016	Ceyhan
Flood	1998	8	10	60		Trabzon
Earthquake	1999	8	17	17127	43953	Marmara
Earthquake	1999	9	13	6	422	Kocaeli
Earthquake	1999	10	5		103	Marmaris
Earthquake	1999	8	31	1	166	Izmit
Earthquake	1999	11	11	1	200	Sakarya
Earthquake	1999	11	12	845	4948	Düzce,Bolu
Earthquake	2000	5	8	1		Puturge
Flood	2000	5	27	2		Samsun
Earthquake	2000	6	6	3	81	Çankiri
Earthquake	2001	7	10		46	Erzurum
Slide	2001	11	10	9		Trabzon
Earthquake	2001	6	25		130	Osmaniye
Earthquake	2001	7	10		46	Erzurum
Slide	2001	11	10	9		Trabzon
Flood	2001	3	9	4		Urfa

Flood	2001	5	7	3		Antakya

APPENDIX-2 Destructive Earthquakes in Turkey

Destructive Earthquakes in Turkey									
DD/MM/YY	**Magnit. (Ms)**	**Region**	**# of deaths**	**# of injured**	**# of heavily damage houses**	**Latitu. (N)**	**Longitu. (E)**	**Dpth (km)**	**Inten. (MSK)**
09.03.1902	5.6	Çankiri	4	-	3000	40.65	33.60	-	-
28.04.1903	6.7	Malazgirt	2626	-	4500	39.10	42.50	-	IX
10.02.1903	5.8	Zara	-	-	1500	39.90	37.80	-	-
04.12.1905	6.8	Çemisgeze	-	-	15	39.00	39.00	30	-
09.08.1912	7.3	Mürefte	216	466	5540	40.60	27.20	16	-
04.10.1914	5.1	Afyon-Bolvadin	400	-	1700	38.00	30.00	15	-
13.05.1924	5.3	Çaykara	50	-	700	40.00	42.00	30	-
13.09.1924	6.9	Pasinler	310	-	4300	39.96	41.94	10	-
07.08.1925	5.9	Afyon-Dinar	3	-	2043	38.10	29.80	20	IX
08.02.1926	4.7	Milas	2	-	598	36.80	27.10	30	-
18.03.1926	6.9	Finike	27	-	190	35.84	29.50	10	-
22.10.1926	5.7	Kars	355	-	1100	40.94	43.88	10	VIII
31.03.1928	7	Izmir-Torbali	50	-	2100	38.18	27.80	10	IX
18.05.1929	6.1	Sivas-Susehri	64	-	1357	40.20	37.90	10	VIII
06.05.1930	7.2	Hakkari Siniri	2514	-	3000	37.98	44.48	70	X
19.07.1933	5.7	Denizli-Çivril	20	-	200	38.19	29.79	40	VIII
15.12.1934	4.9	Bingöl	12	-	200	38.85	40.55	-	-
04.01.1935	6.7	Erdek	5	30	600	40.40	27.49	30	IX
01.05.1935	6.2	Digor	200	-	1300	40.09	43.22	60	-
23.03.1936	4.5	Kars-Kötek	-	-	100	39.00	42.00	30	-
19.04.1938	6.6	Kirsehir	149	-	3860	39.44	33.79	10	IX
18.06.1938	6.4	Yenice	65	36	670	39.99	27.36	10	IX
22.09.1939	7.1	Izmir-Dikili	60	-	1235	39.07	26.94	10	IX
21.11.1939	5.9	Tercan	43	-	500	39.82	39.71	80	-
26.12.1939	7.9	Erzincan	32962	-	116720	39.80	39.51	20	X-XI

APPENDIX 2 Destructive Earthquakes in Turkey Continued

DD/MM/YY	Magnit. (Ms)	Region	# of deaths	# of injured	# of heavily damage houses	Latitu. (N)	Longitu (E)	Dpth. (km)	Inten. (MSK)
20.02.1940	6.7	Kayseri-Develi	37	20	530	38.40	35.30	30	VIII
13.04.1940	5.6	Yozgat	20	-	1250	40.04	35.20	30	-
10.01.1940	5	Nigde	58	-	586	38.00	34.70	-	-
10.09.1941	5.9	Van-Ercis	194	-	600	39.45	43.32	20	VIII
12.11.1941	5.9	Erzincan	15	-	500	39.74	39.43	70	-
15.11.1942	6.1	Bigadiç-Sindirgi	7	-	1262	39.55	28.55	10	VIII
21.11.1942	5.5	Osmancik	7	-	448	40.82	34.44	80	-
20.12.1942	7	Niksar-Erbaa	3000	6300	32000	40.87	36.47	10	IX
11.12.1942	5.9	Çorum	25	-	816	40.76	34.83	40	-
20.06.1943	6.6	Adapazari-Hendek	336	-	2240	40.85	30.51	10	IX
26.11.1943	7.2	Tosya-Ladik	2824	-	25000	41.05	33.72	10	IX-X
01.02.1944	7.2	Bolu-Gerede	3959	-	20865	41.41	32.69	10	IX-X
06.10.1944	7	Ayvalik-Edremit	27	-	1158	39.48	26.56	40	IX
05.04.1944	5.6	Mudurnu	30	-	900	40.84	31.12	10	-
25.06.1944	6.2	Gediz-Usak	21	-	3476	38.79	29.31	40	VIII
20.03.1945	6	Adana-Ceyhan	10	-	650	37.11	35.70	60	VIII
13.08.1945	6.3	Kursunlu	32	58	1354	40.88	32.87	10	IX
21.02.1946	5.6	Kadinhan-Ilgin	2	-	509	38.24	31.79	60	VIII
31.05.1946	5.7	Varto-Hinis	839	349	1986	39.29	41.21	60	VIII
23.07.1949	7	Izmir-Karaburun	1	7	824	38.57	26.29	10	IX
17.08.1949	7	Karliova	450	-	3000	39.60	40.60	40	IX
04.02.1950	4.6	Kigi	20	-	100	39.50	40.60	30	-
08.04.1951	5.7	Iskenderu	6	10	13	36.58	35.85	50	-
13.08.1951	6.9	Kursunlu	52	208	3354	40.88	32.87	10	IX

APPENDIX 2 Destructive Earthquakes in Turkey Continued

DD/MM/YY	Magnit. (Ms)	Region	# of deaths	# of injured	# of heavily damage houses	Latitu. (N)	Longitu (E)	Dpth. (km)	Inten. (MSK)
16.07.1955	7	Aydin-Söke	23	-	470	37.65	27.26	40	IX
20.02.1956	6.4	E.sehir	2	-	1219	39.89	30.49	40	VIII
25.04.1957	7.1	Fethiye	67	-	3100	36.42	28.68	80	IX
26.05.1957	7.1	Bolu-Abant	52	100	4201	40.67	31.00	10	IX
25.10.1959	5	Hinis	18	-	300	39.25	41.63	50	-
26.02.1960	4	Bitlis	-	-	80	38.49	41.52	40	-
26.07.1960	4.6	Tokat	-	-	22	40.56	37.25	40	-
23.05.1961	6.5	Marmaris	-	9	61	36.80	28.70	70	-
10.02.1962	4	Mus	-	-	97	38.70	41.45	-	-
04.09.1962	5.3	Igdir	1	22	-	39.96	44.13	40	-
11.03.1963	5.5	Denizli	-	-	54	37.96	29.14	40	-
18.09.1963	6.3	Çinarcik-Yalova	1	26	230	40.77	29.12	40	VII
24.03.1964	4	Siirt	1	-	100	37.95	42.00	-	-
14.06.1964	6	Malatya	8	36	678	38.13	38.51	3	VIII
06.10.1964	7	Manyas	23	130	5398	40.30	28.23	24	IX
13.06.1965	5.7	Denizli-Honaz	14	217	488	37.85	29.32	33	VIII
31.08.1965	5.6	Karliova	-	-	1500	39.30	40.79	33	-
07.03.1966	5.6	Varto	14	75	1100	39.20	41.60	26	VIII
12.07.1966	4	Varto	12	-	90	39.17	41.56	-	-
19.08.1966	6.9	Varto	2394	1489	20007	39.17	41.56	26	IX
22.07.1967	7.2	Adapazari	89	235	5569	40.67	30.69	33	IX
26.07.1967	6.2	Pülümür	97	268	1282	39.54	40.38	30	VIII
30.07.1967	6	Akyazi	2	40	-	40.70	30.40	18	-
24.09.1968	5.1	Bingöl-Elazig	2	40	-	39.20	40.20	8	-
03.09.1968	6.5	Amasya-Bartin	29	231	2073	41.81	32.39	5	VIII

APPENDIX 2 Destructive Earthquakes in Turkey Continued

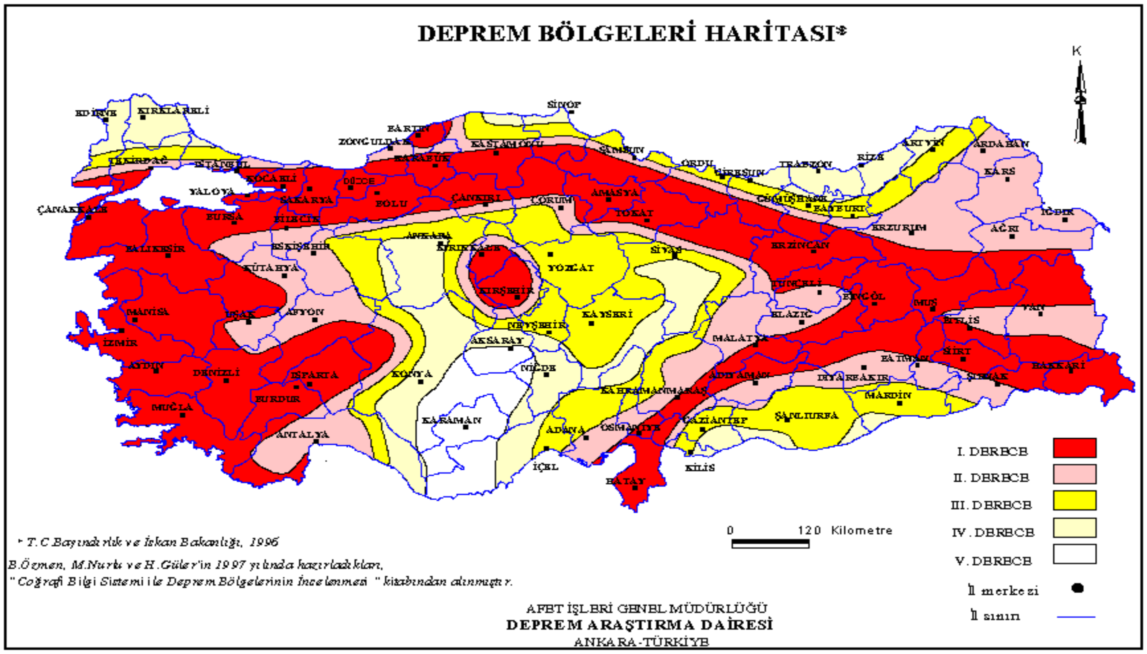
DD/MM/YYYY	Magnit. (Ms)	Region	# of deaths	# of injured	# of heavily damaged houses	Latitud (N)	Longitu (E)	Depth (km)	Intensi (MSK)
25.03.1969	6	Demirci	-	-	1826	39.25	28.44	37	-
28.03.1969	6.6	Alasehir	41	186	4372	38.55	28.46	4	VIII
06.04.1969	5.6	Karaburun	-	3	443	38.50	26.40	16	-
28.03.1970	7.2	Gediz	1086	1260	9452	39.21	29.51	18	IX
19.04.1970	5.9	Çavdarhisar-Kütahya	-	2	41	39.10	29.70	18	-
23.04.1970	5.7	Demirci	-	43	150	39.10	28.70	28	-
02.07.1970	4.8	Gürün	1	-	150	38.80	36.70	19	VIII
12.05.1971	6.2	Burdur	57	150	1389	37.64	29.72	30	VIII
22.05.1971	6.7	Bingöl	878	700	5617	38.85	40.52	3	VIII
26.04.1972	5	Ezine	-	-	400	39.50	26.30	25	-
22.03.1972	4.7	Sarikamis	-	4	100	40.40	42.20	2	-
16.07.1972	5.2	Van	1	-	400	38.30	43.30	46	-
01.02.1974	5.2	Izmir	2	20	47	38.55	27.22	31	VI
06.09.1975	6.9	Lice	2385	3339	8149	38.47	40.72	32	VIII
25.03.1975	5.1	Kars-Susuz	2	26	762	40.95	42.96	25	VI
19.08.1976	4.9	Denizli	4	28	887	37.67	29.17	-	VII
24.11.1976	7.2	Çaldiran-Muradiye	3840	497	9552	39.12	44.16	10	IX
02.04.1976	4.8	Dogu Beyazit	5	13	236	39.91	43.76	14	VI
30.04.1976	5	Ardahan	4	-	300	41.20	42.60	-	-
25.03.1977	4.8	Lice	8	17	210	38.58	40.03	29	-
26.03.1977	5.2	Palu	8	26	842	39.34	43.50	25	-
09.12.1977	4.8	Izmir	-	-	11	38.56	27.47	-	-
16.12.1977	5.3	Izmir	-	-	40	38.40	27.19	24	-
30.06.1981	4.4	Antakya	-	-	2	36.17	35.89	63	-
27.03.1982	5.2	Mus-Bulanik	-	-	424	39.23	41.90	38	-
05.07.1983	4.9	Biga	3	-	85	40.33	27.21	7	-
30.10.1983	6.8	Erzurum-Kars	1155	1142	3241	40.20	42.10	16	VIII
18.09.1984	5.9	Erzurum-	3	35	187	40.90	42.24	10	-

APPENDIX 2 Destructive Earthquakes in Turkey Continued

DD/MM/YYYY	Magnit. (Ms)	Region	# of deaths	# of injured	# of heavily damaged houses	Latitud (N)	Longitu (E)	Depth (km)	Intensi (MSK)
05.05.1986	5.8	Malatya-Sürgü	8	24	824	37.95	37.80	10	VII
06.06.1986	5.6	Sürgü-Malatya	1	20	1174	38.01	37.91	11	-
07.12.1988	6.9	Kars-Akyaka	4	11	546	40.96	44.16	5	-
13.03.1992	6.8	Erzincan-Tunceli	653	3850	6702	39.68	39.56	27	VIII
01.10.1995	5.9	Dinar	94	240	4909	38.18	30.02	24	VIII
27.06.1998	5.9	Adana-Ceyhan	146	94-0	4000	36.85	35.55	23	-
17.08.1999	7.4	17 Agustos Kocaeli	15000	32000	50000	40.70	29.91	20	IX

Source: Bagci, G., Yatman, A., Özdemir, S., Altin, N., “ Türkiye'de Hasar Yapan Depremler, ” Deprem Arastirma Bülteni, Vol. 69, 113-126.

APPENDIX 3 Earthquake map of Turkey



APPENDIX 4

Activities Carried Out by Civil Defence in 1902-2001

Date of Disaster	Place and Type of Disaster	Dead	Alive
13 March 1992	Erzincan-Earthquake	34	4
13 July 1995	Isparta / Senirkent-Flood	37	1
1 October 1995	Afyon / Dinar-Earthquake	23	9
4 November 1995	Izmir-Flood	2	-
27 November 1995	Alanya-Flood	1	-
22 March 1998	Bingöl and Tunceli-Avalanche	4	-
21 May 1998	West Black Sea-Flood	1	101
27 June 1998	Ceyhan-Earthquake	62	2
11 Agust 1998	Trabzon / Köprübasi-Flood	1	-
14 January 1999	Maras / Ekinözü-Avalanche	-	3
7 July 1999	Erzurum / Askale- Flood	2	-
6 June 2000	Çankiri / Orta-Earthquake	1	-
8 May 2001	Hatay / Samandag-Flood	-	3

APPENDIX 5

Activities of the Civil Defence Units in the Marmara and Düzce Earthquakes

Name of the Unit	Personnel	Place of Disaster	Dead	Alive
Ankara Civil Defence SAR Unit	60	Sakarya	116	73
		Kocaeli	60	39
		Gölcük	66	24
		Total	242	136
Istanbul Civil Defence SAR Unit	24	Avcilar	20	13
		Izmit	8	-
		Total	28	13
Erzurum Civil Defence SAR Unit	26	Yalova	79	45
		Total	79	45
Ankara Civil Defence SAR Unit	59	Bolu	23	8
		Düzce	-	1
		Kaynasli	12	9
		Total	35	18
Istanbul Civil Defence SAR Unit	24	Kaynasli	9	9
		Total	9	9
Erzurum Civil Defence SAR Unit	25	Düzce	12	3
		Total	12	3
TOTAL	218	-	405	224

APPENDIX 6

Natural Disaster Profile of Sector 1

Counties	First Priority	# of Occurance	Year	Death	Affected Buildings
Erdek	Earthquake	1	1935	5	600
Bigadiç	Earthquake	1	1942	7	1262
Edremit	Earthquake	1	1947	27	1152
Manyas	Earthquake	1	1967	23	5398
Harman	Earthquake	1	1949		150
Ezine	Earthquake	1	1972		400
Biga	Earthquake	1	1983	3	85
Edirne	Earthquake	1	1953		323
Kocaeli	Earthquake	3	1999 1999 1999	15000 1 1	50000 422 166
Çavdar	Earthquake	1	1970		41
Gediz	Earthquake	1	1970	1086	9452
Sakarya	Earthquake	2	1967 1999	89 2	556 200
Hendek	Earthquake	1	1943	336	2200
Mürefte	Earthquake	1	1912	216	5540
Çinarcik	Earthquake	1	1963	1	230

APPENDIX 7

Natural Disaster Profile of Sector 2

Counties	First Priority	# of Occurance	Year	Death	Affected Buildings
Ceyhan	Earthquake	2	1945 1998	10 146	650 4000
Misis	Earthquake	1	1952	10	511
Bahçe	Earthquake	2	1966 1966		91 100
Amasya	Earthquake	1	1968	29	2073
Lice	Earthquake	2	1975 1977	2385 8	8100 210
Giresun	Flood	1	1991	51	4500
Çanakçi	Flood	1	2000		
Kesap	Flood	1	2000		
Piraziz	Flood	2	2000 2001		
Yaglidere	Flood	1	2000		
Görele	Flood	1	2001		
Hatay	Flood	2	2000 2001	3	1500
Samandag	Flood	2	2000 2001		
Dörtyol	Flood	2	2000 2001		
Iskenderun	Flood	1	2001		
Erzin	Flood	1	2001		
Hassa	Flood	1	2001		
Yayladag	Flood	1	2001		
Içel	Flood	1	2001	4	500
Ünye	Flood	1	2000		
Fatsa	Flood	1	2000		
Gölköy	Flood	1	2000		
Samsun	Flood	1	2000	1	250
Alaçam	Flood	1	2000		
Bafra	Flood	1	2000		
Çarsamba	Flood	1	2000		
Terme	Flood	1	2000		
Türkeli	Flood	1	2000		
Niksar	Earthquake	1	1942	3000	32000
Tokat	Earthquake	1	1960		22
Osmaniye	Earthquake	1	2001		350
Malatya	Earthquake	1	1964	8	678
Pütürge	Earthquake	1	2000		1000

APPENDIX 8

Natural Disaster Profile of Sector 3

Counties	First Priority	# of Occurance	Year	Death	Affected Buildings
Dogubeyazit	Earthquake	1	1976	5	236
Bingöl	Earthquake	2	1934 1971	12 878	200 5617
Karliova	Earthquake	2	1949 1965	450	3000 1500
Bitlis	Earthquake	1	1960		80
Elazig	Earthquake	1	1968	2	
Palu	Earthquake	1	1977	8	842
Erzincan	Earthquake	3	1939 1941 1992	32962 15 653	12500 500 6702
Tercan	Earthquake	1	1936	43	500
Erzurum	Earthquake	2	1983 2001	1155	3240 85
Hinis	Earthquake	1	1959	18	300
Balkaya	Earthquake	1	1984	3	187
Askale	Earthquake	1	1999	2	50
Pasinler	Earthquake	1	1924	310	4300
Hasankale	Earthquake	1	1952	133	701
Gümüshane	Flood	1	1990	20	2000
Çukurca	Avalanche	3		20	2000
Hakkari	Avalanche	13		13	206
Semdinli	Avalanche	3		6	23
Yüksekova	Avalanche	9		85	167
Kars	Earthquake	1	1926	355	1100
Akyaka	Earthquake	1	1988	4	546
Sarkamis	Earthquake	1	1972		100
Susuz	Earthquake	1	1975	2	762
Digor	Earthquake	1	1935	200	1300
Malazgirt	Earthquake	1	1903	2625	4500
Mus	Earthquake	1	1962		97
Bulanik	Earthquake	1	1982		424
Varto	Earthquake	3	1946 1966 1966	839 28 2394	1986 1100 2000
Iyidere	Flood	1	2000		
Çaldiran	Earthquake	1	1976	3840	9552
Siirt	Earthquake	1	1964	1	100
Trabzon	Flood	2	1990 2000	55	4500

APPENDIX 9

Natural Disaster Profile of Sector 4

Counties	First Priority	# of Occurance	Year	Death	Affected Buildings
Dinar	Earthquake	2	1925 1995	3 94	2043 4909
Antalya	Earthquake	1	1926	27	190
Germencik	Earthquake	1	1960		100
Söke	Earthquake	1	1955	23	470
Bolvadin	Earthquake	1	1914	400	1700
Burdur	Earthquake	1	1971	57	1389
Çivril	Earthquake	1	1933	20	200
Honaz	Earthquake	1	1965	14	488
Denizli	Earthquake	2	1963 1976	4	54 887
Gönen	Earthquake	1	1969	1	20
Izmir	Earthquake	3	1947 1977 1977	2	47 11 40
Foça	Earthquake	1	1979		22
Torbali	Earthquake	1	1928	50	2100
Dikili	Earthquake	1	1939	60	1235
Karaburun	Earthquake	3	1949 1953 1969	1	827 73 443
Ilgin	Flood	1	2000	2	509
Cumra	Flood	1	2000		
Derbent	Flood	1	2000		
Emirgazi	Flood	2	2000 2001		
Eregli	Flood	1	2001		
Demirci	Earthquake	3	1969 1969 1970		1100 1826 150
Alasehir	Earthquake	1	1969	41	4372
Fethiye	Earthquake	2	1957 1969	67	3100 42
Marmaris	Earthquake	2	1961 1999		61 103
Milas	Earthquake	1	1926	2	598
Köycegiz	Earthquake	1	1959		59
Mugla	Earthquake	2	1941 1941	2	400 500
Usak	Earthquake	1	1944	21	3476

VITA

Murat Ulug was born on May 1, 1974 in Kirikkale, Türkiye. He received his high school education at Maltepe Military High School, Izmir. He has graduated from the Department of System Enginering, Turkish Army Academy in Ankara (1996), he has served in the Turkish Army, (1997-2001). In September 2001, he started his graduate study at the Department of Industrial Engineering at Bilkent University.

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