

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**DEVELOPEMENT OF A DECISION SUPPORT MODEL FOR THE OPTIMUM
SHELTER LOCATION FOLLOWING A DISASTER**

M.Sc. THESIS

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Department of Geomatics Engineering

Geomatics Engineering Programme

Thesis Advisor: Asst. Prof. Dr. Himmet KARAMAN

MAY 2014

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

**AFET SONRASI EN UYGUN GEÇİCİ BARINMA ALANLARININ
BELİRLENMESİ İÇİN KARAR DESTEK MODELİ GELİŞTİRİLMESİ**

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To my family,

FOREWORD

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ABBREVIATIONS

AFAD	: Afet ve Acil Durum yönetimi başkanlığı (Emergency Situations Directorate of Turkey)
AHP	: Analytical Hierarchy Process
AKUT	: Arama Kurtarma Derneği (Search and Rescue Association)
CI	: Consistency Index
CR	: Consistency Ratio
DASK	: Doğal Afet Sigorta Kurumu (Turkish Catastrophe Insurance Pool)
DRMC	: Disaster Risk Management Cycle
FEMA	: Federal Emergency Management Agency
GEA	: Global Engineering Alliance
GPS	: Global Positioning System
GIS	: Geographical Information Systems
GSM	: Global System for Mobile Communications
JICA	: Japan International Cooperation Agency
MAG	: Mahalle Afet Gönüllüleri (Neighborhood Disaster Volunteers)
NGO	: Non-Governmental Organizations
ODTÜ	: Orta Doğu Teknik Üniversitesi (Middle-east Technical University)
OFDA	: Office of U.S. Foreign Disaster Assistance
RI	: Random Consistency Index
RS	: Remote Sensing
TSS	: Technical Support Section
UN	: the United Nations
UNHCR	: the United Nations High Commissioner for Refugees
USGS	: United States Geological Survey
WHO	: World Health Organization

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DEVELOPMENT OF A DECISION SUPPORT MODEL FOR THE OPTIMUM SHELTER LOCATION FOLLOWING A DISASTER

SUMMARY

Establishment of temporary shelters are most widely used method for protecting or sustaining the lives (in an optimum level of standards) of the victims who may have suffered from disasters, social congestions or wars. UNHCR (United Nations Refugee Agency) is one of the efficient organizations acting in this area and their reports are important guides in means of supplying know-how in designing, maintaining and selecting the right locations for shelters. Similar to UNHCR, Humanitarian Charter and Minimum Standards in Humanitarian Response-Sphere Project is concerned with the righteous conditions in shelters and the Sphere Handbook is a valuable product that describes the details of sheltering processes gained by the experiences of the initiative. In addition to these international bodies, temporary shelters established after 2012 Van Earthquake and camps for Syrian refugees are good examples for showing the experience and awareness of the Turkish institutions especially AFAD (Presidency of Disaster and Emergency Management) and Turkish Red Crescent (KIZILAY). These examples also have a characteristic that serves as a reminder for the importance of the issue.

It is shown by several scientific studies that Istanbul may face a big scale earthquake in near future. The main axis of these studies is to assess the vulnerability and estimate the possible results due the adverse conditions of the earthquake. These studies claim that one of the most important issues is the requirement of temporary shelter for the victims. To meet the needs of the victims there are several physical conditions in addition to social components that need to be considered. It was estimated in the study (A Disaster Prevention / Mitigation Basic Plan in Istanbul-2002) carried out by Istanbul Metropolitan Municipality and JICA that in a case of the possible earthquake 330.000 tents and 120 km² area will be needed according to the standards of World Health Organization (WHO), which are 4.5 -5.5 m² space for each person and hosting maximum 10,000 to 12,000 people. It is almost impossible to estimate the physical conditions and social problems that may occur in such a situation. Although there have been made many improvements in the next 10 years of this study, current building stock and infrastructure is still questionable and it can be assumed that requirement for

huge amounts of shelter will be needed. In this aspect one of the critical challenges is the determination of the location of these shelter areas.

In this study it is aimed at developing a decision support model that will generate solution for the problem of temporary shelter site selection in the aftermath of a disaster. It is planned to base this model on AHP and/or Fuzzy AHP methodologies also benefiting from spatial analysis through a GIS software. Thus the correct locations for these areas will be determined before earthquake and it will be available for the decision makers to develop strategies to enhance and rehabilitate these areas. The system will also be efficient in post-earthquake situation for evaluating the selected sites. Moreover it will be available to re-evaluate the efficiency of the shelter locations based on the new conditions that arise because of the earthquake. Therefore decision makers will be allowed to update the criteria simultaneously and new locations based on these optimum conditions will be assessed. Inexistence of such a study in Turkey proves the importance of this study and high lights the emergence of the situation.

AFET SONRASI GEÇİCİ BARINMA ALANLARININ BELİRLENMESİ İÇİN KARAR DESTEK MODELİ GELİŞTİRİLMESİ

ÖZET

Geçici barınma alanlarının kurulması; dünyanın birçok noktasında kimi zaman afetler, kimi zaman toplumsal karışıklıklar, kimi zaman da savaşlar nedeniyle mağdur duruma düşen insanları korumak ve hayatlarını belli standartlarda da olsa yürütmelerini sağlamak amacıyla başvurulmuş yönetimlerden en yaygınıdır. UNHCR (Birleşmiş Milletler Mülteci Yüksek Komiserliği) bu anlamda uluslararası faaliyet gösteren etkin kurumların başında yer alır ve yayınladıkları raporlar ile bu barınma alanlarının ilk andan son ana kadar ne şekilde tasarlanması gerektiğini, yer seçiminde hangi kriterlere dikkat edilmesi gerektiğine dair çeşitli bilgileri dünya kamuoyu ile paylaşmaktadır. Buna benzer olarak yine uluslararası bir girişim olan Humanitarian Charter and Minimum Standards in Humanitarian Response-Sphere Project geçici barınma alanlarına dair geçerli tüm süreci ayrıntılı bir biçimde tanımlamakta ve edindiği tecrübeler ile bu konunun ne kadar büyük bir öneme sahip olduğunu vurgulamaktadır. Bu kuruluşlara ek olarak Türkiye’de 2012 Van depreminden sonra kurulan çadır kentler, Suriyeli mültecilerin sığındığı kamplar başta AFAD ve Türk KIZILAY’ı olmak üzere Türk kurumlarının bu konudaki tecrübelerinin değerlendirildiği güncel örnekler olarak bulunmaktadır. Bu örnekler ayrıca geçici barınma alanları konusunun önemini ortaya koymaları açısından da hatırlatıcı bir niteliğe sahiptir.

Yakın bir gelecekte İstanbul’un büyük ölçekli bir depreme maruz kalacağı çeşitli bilimsel araştırmalarla ortaya konmuştur. Bu çalışmaların ana eksenini İstanbul’un hasar görebilirliğini ortaya koymakla birlikte mevcut yapının nasıl sonuçlar doğuracağına dair konuyla ilgili tüm paydaşları aydınlatmaktır. Araştırmalar göstermektedir ki olası bir İstanbul depremi sonrası önem taşıyan başlıca konulardan biri, konutları yaşanmaz hale gelmiş olan insanların barınma ihtiyacıdır. Bu ihtiyacın karşılanabilmesi fiziki birçok unsurun değerlendirilmesini gerektirmekte ve ayrıca sosyal açıdan da çeşitli değişkenleri içermektedir. 2002 yılında İstanbul Büyükşehir Belediyesi ve JICA ortaklığıyla gerçekleştirilen İstanbul Afet Önleme Azaltma Temel Planı bu noktaya işaret etmekte ve yaklaşık 330.000 adet çadıra ve 120 km²’lik çadır alanına ihtiyaç duyulduğu belirtilmektedir. Bu değerlerin yaratacağı fiziki koşulları ve sosyal

sıkıntıları kestirmek neredeyse imkansızdır. Aradan geçen 10 senede İstanbul'un fiziki dokusuna yönelik birtakım iyileştirmeler yapılmış olsa da, İstanbul'daki mevcut yapı stoku ve altyapı durumu göz önünde bulundurulduğunda gerçekleşecek hasarın halen büyük miktarda barınma ihtiyacı doğuracağı öngörülmektedir. Bu doğrultuda ele alınması gereken en temel unsurlardan biri geçici barınma alanlarının kentin hangi noktalarında konuşlandırılacağıdır.

Bu çalışmada İstanbul'un yüz yüze olduğu bu önemli sorununa çözüm üretmek amacıyla, söz konusu geçici barınma alanlarının yer seçimi sürecine katkıda bulunacak bir karar destek modeli geliştirilmesi hedeflenmektedir. Bu modelin analitik hiyerarşi yöntemi (AHY), yaklaşımlarını temel alarak mekansal analiz gerçekleştirebilecek kapasitede ve Coğrafi Bilgi Sistemleri (CBS) yazılımı tabanlı olması öngörülmektedir. Bu sayede karar vericilerin olası bir deprem öncesinde en doğru geçici yerleşim alanlarını tespit etmesi ve bu alanların rehabilite edilmesi doğrultusunda stratejiler geliştirmesi mümkün olacaktır. Kurulması öngörülen sistem, olası bir afet sonrasında da söz konusu alanların değerlendirilmesi amacıyla kullanılabilen bir yapıya sahip olacaktır. Ek olarak çok kriterli analizi mümkün kılması sebebiyle, afet sonrası koşulları dikkate alınarak kriterlerde anlık güncellemeler gerçekleştirilebilecek ve bu sayede acil durum anında tercih edilebilecek optimum konumların tespiti sağlanabilecektir. Türkiye'de benzeri bir sistemin bulunmuyor oluşu çalışmanın önemini daha da ön plana çıkarmakta ve aciliyetini ortaya koymaktadır.

Analitik Hiyerarşi Yöntemi Çok Kriterli Karar Verme Yöntemleri'nin en sık kullanılanıdır. Çok Kriterli Karar Verme Yöntemleri'ni kullanmaktaki amaç, alternatif ve kriter sayılarının fazla olduğu durumlarda karar verme mekanizmasını kontrol altında tutabilmek ve karar sonucunu mümkün olduğu kadar kolay ve çabuk elde etmektir. AHP, karar vericinin; tüm alternatifleri tüm kriterler altında değerlendirerek, göreceli önemlerine göre ikili karşılaştırmalar yapmasına dayanmaktadır.

Bu çalışma esnasında ulusal ve uluslararası geçici barınma standartlarını göze aldıktan sonra geçici çadır alanları için kriterler belirlenmiştir. Aynı zamanda Türkiye'deki ve dünyadaki afetler göz önüne alınıp onların hangi sorunlarla karşılaştıkları ortaya konmuştur.

Yer seçimi eylemi öncelikle bir yer seçimi kararının alınmasıyla başlamaktadır. Sonraki adımda yer seçimi faktörleri tanımlanmaktadır. İlgili faktörlerin ağırlıkları belirlendikten sonra her bir olası yerleşimin sıralanması başarılmaktadır. Karşılaştırma

sonuçları analiz edilerek tercih edilen yerleşimlerin tanımlanması ve en uygun yerleşimin önerilmesiyle işlem sonlanmaktadır.

1. INTRODUCTION

Site selection, planning and the preparation of shelter have a direct bearing on the preparation of other assistance. These will be important considerations in the overall needs assessment and planning of response. Decisions must be made using an integrated approach, incorporating both the advice of specialists and the views of the refugees (UN, 2007).

Sources of information for site selection and planning should include local authorities and communities, government offices, educational institutions and UN agencies. UNHCR Headquarters, through the focal point on Geographical Information Systems (GIS), can also support operations with maps, aerial photographs, satellite images and a special geographic database. Furthermore, the Technical Support Section (TSS) at Headquarters, upon request, could assist in the process of site selection and planning (UN, 2007).

The social and cultural backgrounds of the refugees are important determinants in site selection, physical planning and shelter. In many situations, however, options will be limited and land that meets even minimum standards may be rare. It is therefore wise to put on record the shortcomings of the site and the rationale for its selection (UN, 2007).

1.1 Purpose of Thesis

Istanbul lies on an active seismic zone ranging from Java – Myanmar – Himalaya – Iran – Turkey and Greece, (**Figure 1.1**) where many large earthquakes have occurred in the past. Based on worldwide historical earthquake catalogues, Istanbul (Constantinople) has experienced earthquakes equal or greater than intensity 9 at least 14 times from 5th century. This means Istanbul has suffered damages due to earthquakes every 100 years, on average. (Segawa and others, 2004)

Looking back to Turkey's earthquake history, there are two recent strong earthquakes:

1999 Izmit, Kocaeli: which occurred with a moment magnitude of 7.4 on 17 August at about 3:02 a.m. local time. The event lasted for 37 seconds, killing 17,127 and injuring 43,959 people and leaving approximately half a million people homeless. Reports from September 1999 show that 120,000 poorly engineered houses were damaged beyond repair, 30,000 houses were heavily damaged, 2,000 other buildings collapsed and 4,000 other buildings were heavily damaged. 300,000 people were left homeless after the earthquake. The estimated amount of damage is equivalent to 23 billion dollars (USD) (Marza, 2008)

2012 Van: The Van earthquake was a destructive magnitude 7.1 earthquake that struck eastern Turkey near the city of Van on Sunday, 23 October 2011 at 13:41 local time. It occurred at a shallow depth of 20 kilometers (12 mi), causing heavy shaking across much of eastern Turkey and lighter tremors across neighboring parts of the South Caucasus and Levant. According to Disasters and Emergency Situations Directorate of Turkey AFAD on 30 October, the earthquake killed 604 and injured are 4,152. At least 11,232 buildings sustained damage in the region, 6,017 of which were found to be uninhabitable. The uninhabitable homes left as much as 8,321 households with an average household population of around 7.6 homeless in the province; this could mean that at least around 60,000 people were left homeless. The other 5,215 have been damaged but are habitable.

Suitable, well-selected sites and soundly planned refugee settlements with adequate shelter and integrated, appropriate infrastructure are essential from the early stages of a refugee emergency, as they are life-saving and alleviate hardship. Accommodating refugees in emergencies may take place in host families/communities, or take the form of mass accommodation in existing shelters or organized camps. Initial decisions on the location of the camp should involve the host government as well as local authorities and communities. Likewise, layout should involve the refugees. This approach is necessary to avoid long-term protection issues, such as opposition with local communities; it will also help to ensure a safe environment for the refugees and the delivery of humanitarian assistance (UN, 2007).

It is obvious that, the expected earthquake for the Istanbul will cause inescapable and irreversible consequences for human life. That is why, temporary shelter sites should be estimated that which regions will be safer, to be prepared as good as possible to the expected earthquake.

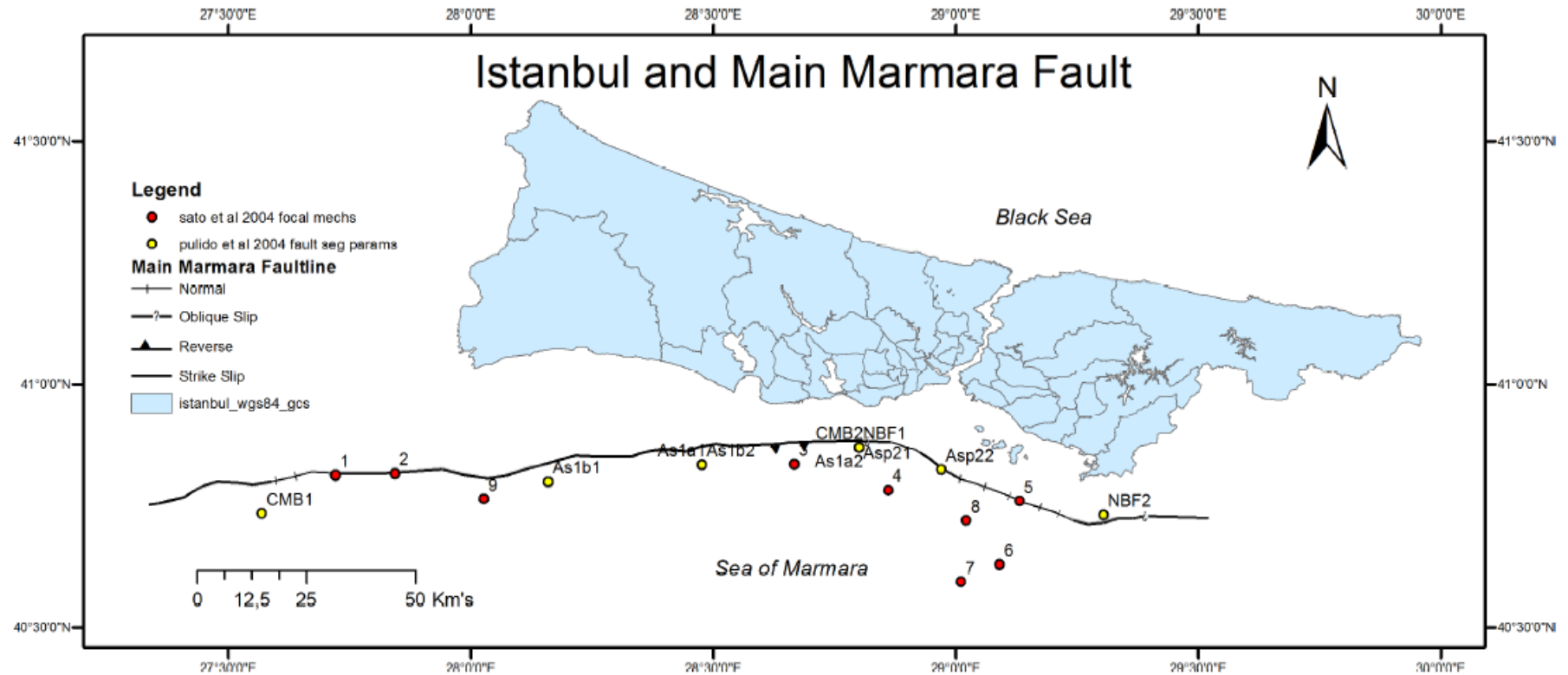


Figure 1.1 : Main Marmara fault line and the focal parameter locations. (Erden T., Karaman H., 2012)

2. DISASTER

The word disaster implies a sudden overwhelming and unforeseen event. At the household level, a disaster could result in a major illness, death, a substantial economic or social misfortune. At the community level, it could be a flood, a fire, a collapse of buildings in an earthquake, the destruction of livelihoods, an epidemic or displacement through conflict. When occurring at district or provincial level, a large number of people can be affected. Most disasters result in the inability of those affected to cope with outside assistance. At the household level, this could mean dealing with the help from neighbors; at the national level, assistance from organizations such as the International Federation of Red Cross and Red Crescent Societies, the United Nations, various non-governmental organizations (NGOs) and government agencies themselves. As the limiting factor in disaster response is often the coping capacity of those affected, improving their resilience when responding to disasters is a key approach to lessening the consequence of a disaster. (Saltbones, 2006)

2.1 Natural Disaster

These types of disaster naturally occur in proximity to, and pose a threat to, people, structures or economic assets.(**Figure 2.1**) They are caused by biological, geological, seismic, hydrologic, or meteorological conditions or processes in the natural environment (e.g., cyclones, earthquakes, tsunamis, floods, landslides, and volcanic eruptions) (VUSSC, 2013)



Figure 2.1 : Natural disasters (ABCNetspace, 2013)

2.2 Man-made Disaster

Man-made disasters are specific events where an anthropogenic hazard has come to fruition. An anthropogenic hazard or a human-made hazard can result in the form of a human-made disaster.

Figure 2.2 shows a Man-made disasters which are also known as anthropogenic disasters and they as a result of human intent, error or as a result of failed systems. (Disasterium, 2013)



Figure 2.2 : Man-made disaster (Merchant, 2012)

3. EARTHQUAKE

The Earth – as ecologists always reminds us- is alive, and an earthquake is the unfolding of a series of natural planetary events. An earthquake is just a stretch or a shrug, one normal and expected movement among many. This is simply how the earth behaves. (Clague, 2011).

In simplest terms, an earthquake is a sudden shaking of the ground caused by waves of energy moving through the Earth's crust. We imagine earthquakes as sudden events, yet an earthquake is actually a release of energy (geologists call it a strain) that has built up over decades or hundreds of years. Ultimately, it is the heat from the Earth's molten core that causes the movements that lead to earthquakes (Clague, 2011).

Earthquakes are measured using observations from seismometers. The moment magnitude is the most common scale on which earthquakes larger than approximately 5 are reported for the entire globe. The more numerous earthquakes smaller than magnitude 5 reported by national seismological observatories are measured mostly on the local magnitude scale, also referred to as the Richter scale. These two scales are numerically similar over their range of validity. Magnitude 3 or lower earthquakes are mostly almost imperceptible or weak and magnitude 7 and over potentially cause serious damage over larger areas, depending on their depth. The largest earthquakes in historic times have been of magnitude slightly over 9, although there is no limit to the possible magnitude. The most recent large earthquake of magnitude 9.0 or larger was a 9.0 magnitude earthquake in Japan in 2011 (as of October 2012), and it was the largest Japanese earthquake since records began. Intensity of shaking is measured on the modified Mercalli scale. The shallower an earthquake, the more damage to structures it causes, all else being equal (Ashmita, 2013).

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground. When the epicenter of a large earthquake is located offshore, the seabed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides, and occasionally volcanic activity (Tacio, 2013).

3.1 Earthquake Mechanism and Faults:

As it is shown in **Figure 3.1**, there are four different types of earthquakes: Tectonic, volcanic, collapse and explosion.

A tectonic earthquake is one that occurs when the earth's crust breaks due to geological forces on rocks and adjoining plates that cause physical and chemical changes. (Claire, 2013)

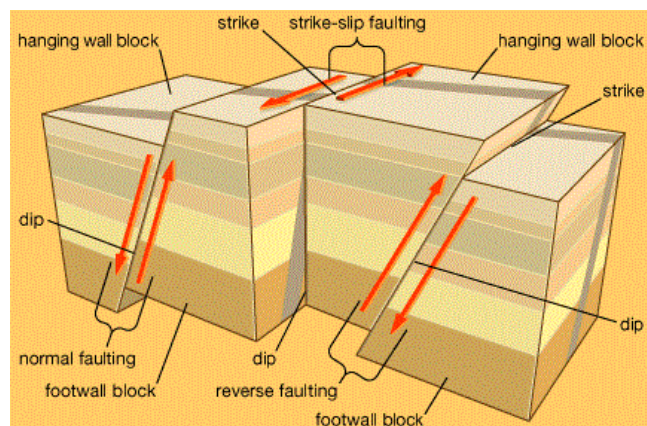


Figure 3.1 : Different types of earthquakes and faults (Cauz, 2014)

A volcanic earthquake is any earthquake that results from tectonic forces which occur in conjunction with volcanic activity. **Figure 3.2** shows what happens in a volcanic earthquake.

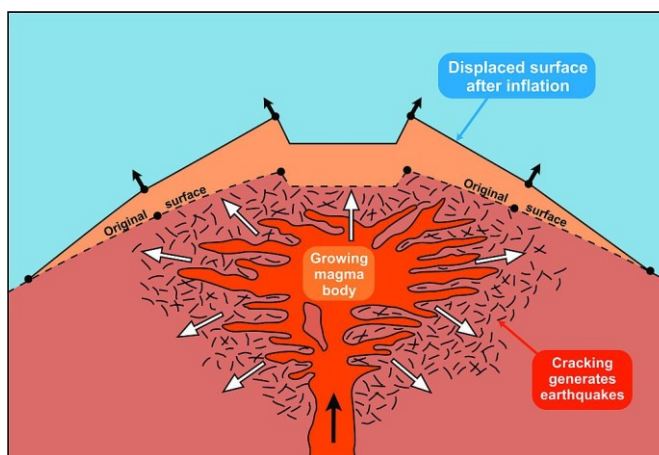


Figure 3.2 : Volcanic earthquake (Page, 2013)

A collapse earthquake are small earthquakes in underground caverns and mines that are caused by seismic waves produced from the explosion of rock on the surface. In **Figure 3.3** some damages caused by a collapse earthquake are shown.



Figure 3.3 : Collapse earthquake (Nasril, 2011)

An explosion earthquake is an earthquake that is the result of the detonation of a nuclear and/or chemical device like **Figure 3.4**.



Figure 3.4 : Explosion earthquake (Nasril, 2011)

As it is shown in **Figure 3.5**, there are three different types of faults: Normal, Reverse, and Trans current (Strike-Slip).

Normal faults form when the hanging wall drops down. The forces that create normal faults are pulling the sides apart, or extensional.

Reverse faults form when the hanging wall moves up. The forces creating reverse faults are compressional, pushing the sides together.

Trans current or Strike-slip faults have walls that move sideways, not up or down (Claire, 2013).

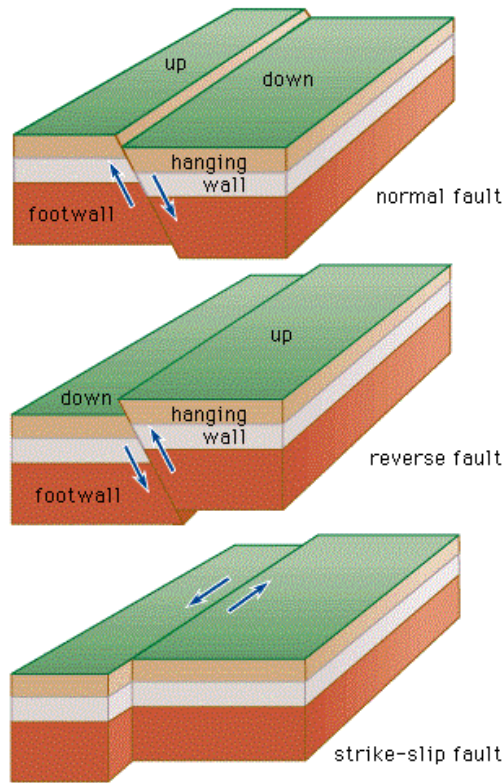


Figure 3.5 : Different types of faults (Alden, 2014)

Reverse faults, particularly those along convergent plate boundaries are associated with the most powerful earthquakes, including almost all of those of magnitude 8 or more. Strike slip faults, particularly continental transforms can produce major earthquakes up to about magnitude 8. Earthquakes associated with normal faults are generally less than magnitude 7. reverse > strike-slip > normal (Wyss, 1979).

3.2 Size and Frequency of Occurrence:

It is estimated that around 500,000 earthquakes occur each year, detectable with current instrumentation. About 100,000 of these can be felt. Minor earthquakes occur nearly constantly around the world in places like California and Alaska in the U.S., as well as in Mexico, Guatemala, Chile, Peru, Indonesia, Iran, Pakistan, the Azores in Portugal, Turkey, New Zealand, Greece, Italy, India and Japan, but earthquakes can occur almost anywhere, including New York City, London, and Australia (Bannan, 2011). **Figure 3.6** shows Strong earthquakes around the world between 1990-2012.

3.3 Strong Earthquakes Around the World

Largest Earthquakes					Deadliest Earthquakes				
Year	Date	Magnitude	Fatalities	Region	Year	Date	Magnitude	Fatalities	Region
1990	07/16	7.7	1621	Luzon, Philippine Islands	1990	06/20	7.4	50000	Iran
1991	04/22	7.6	75	Costa Rica	1991	10/19	6.8	2000	Northern India
1991	12/22	7.6	0	Kuril Islands	1991				
1992	12/12	7.8	2519	Flores Region, Indonesia	1992	12/12	7.8	2519	Flores Region, Indonesia
1993	08/08	7.8	0	South of Mariana Islands	1993	09/29	6.2	9748	India
1994	10/04	8.3	11	Kuril Islands	1994	06/06	6.8	795	Colombia
1995	07/30	8.0	3	Near Coast of Northern Chile	1995	01/16	6.9	5530	Kobe, Japan
1995	10/09	8.0	49	Near Coast of Jalisco Mexico	1995				
1996	02/17	8.2	166	Irian Jaya Region Indonesia	1996	02/03	6.6	322	Yunnan, China
1997	10/14	7.8	0	South of Fiji Islands	1997	05/10	7.3	1572	Northern Iran
1997	12/05	7.8	0	Near East Coast of Kamchatka	1997				
1998	03/25	8.1	0	Balleny Islands Region	1998	05/30	6.6	4000	Afghanistan-Tajikistan Border Region
1999	09/20	7.7	2297	Taiwan	1999	08/17	7.6	17118	Turkey
2000	11/16	8.0	2	New Ireland Region, P.N.G.	2000	06/04	7.9	103	Southern Sumatra, Indonesia
2001	06/23	8.4	138	Near Coast of Peru	2001	01/26	7.7	20023	India
2002	11/03	7.9	0	Central Alaska	2002	03/25	6.1	1000	Hindu Kush Region, Afghanistan
2003	09/25	8.3	0	Hokkaido, Japan Region	2003	12/26	6.6	31000	Southeastern Iran
2004	12/26	9.1	227898	Off West Coast of Northern Sumatra	2004	12/26	9.1	227898	Off West Coast of Northern Sumatra
2005	03/28	8.6	1313	Northern Sumatra, Indonesia	2005	10/08	7.6	80361	Pakistan
2006	11/15	8.3	0	Kuril Islands	2006	05/26	6.3	5749	Java, Indonesia
2007	09/12	8.5	25	Southern Sumatra, Indonesia	2007	08/15	8.0	514	Near the Coast of Central Peru
2008	05/12	7.9	87587	Eastern Sichuan, China	2008	05/12	7.9	87587	Eastern Sichuan, China
2009	09/29	8.1	192	Samoa Islands region	2009	09/30	7.5	1117	Southern Sumatra, Indonesia
2010	02/27	8.8	507	Offshore Maule, Chile	2010	01/12	7.0	316000	Haiti
2011	03/11	9.0	20896	Near the East Coast of Honshu, Japan	2011	03/11	9.0	20896	Near the East Coast of Honshu, Japan
2012	04/11	8.6		off the west coast of northern Sumatra	2012	02/06	6.7	113	Negros-Cebu region, Philippines

Figure 3.6 : Strong earthquakes around the world (USGS, Earthquake hazard program, 2012)

3.3.1 Northridge, US: January 17, 1994

At 4:31 a.m. on January 17, 1994, a 6.7-magnitude quake struck the San Fernando Valley, a densely populated area of Los Angeles located 20 miles northwest of the city's downtown. The sudden rupture of a previously undocumented blind thrust fault caused the earthquake. At least 57 people killed and thousands of buildings destroyed or damaged. The Northridge quake, named after the San Fernando Valley community near its epicenter, was the costliest in U.S. history, with damages estimated at more than \$20 billion (Aurelius, 1994).

The earthquake occurred on a blind thrust fault, and produced the strongest ground motions ever instrumentally recorded in an urban setting in North America. Damage was widespread, sections of major freeways collapsed, parking structures and office buildings collapsed, and numerous apartment buildings suffered irreparable damage. Damage to wood-frame apartment houses was very widespread in the San Fernando Valley and Santa Monica areas, especially to structures with "soft" first floor or lower-level parking garages. The high accelerations, both vertical and horizontal, lifted structures off their foundations and/or shifted walls laterally (Bowes, 2010).

Elastic strain released by the Northridge earthquake measurably deformed the crust over 5000 km² surrounding the epicenter. Observations of the displacements of 60 survey stations determined by means of Global Positioning System (GPS) satellites before and after the earthquake show that the region was lifted up as much as 70 cm and displaced horizontally as much as 21 cm (Earth, 1994). **Figure 3.7** shows an example of damages of Northridge earthquake in 1994.



Figure 3.7 : Northridge earthquake damage (Eplett, 1994)

through the earth sciences and engineering provide us with the knowledge to mitigate future earthquake hazards. These studies include characterization of the earthquake source (using geologic, geodetic, and seismologic data to estimate how large an earthquake can occur with what probability), prediction of the ground motions (given an earthquake of some size at some distance, how will the ground move under a building), and building response (how do buildings behave when subjected to those ground motions). Some of the results from the Northridge earthquake confirmed research over the past decade by the National Earthquake Hazards Reduction Program. Thrust faults concealed below Los Angeles present a threat to the region that approaches that posed by the San Andreas fault. When earthquakes occur directly beneath a city, it will be subjected to ground motions with peak accelerations approaching the force of gravity, exceeding the amounts of shaking anticipated by building codes in some respects. Some of the results, especially concerning the effects of earthquakes, reinforced findings from previous earthquakes. Ground failure induced by shaking can be as extensive as that caused by direct faulting, and the system of concealed faults under Los Angeles is more complex than previously thought, dipping both to the north and south. The severe damage done to two- to four-story residential buildings built over parking garages has important implications for regional housing needs because of the pervasive existence of such structures. Some results were a surprise. The widespread fracturing of welds in steel-frame buildings was unexpected because of the ductility of steel. Understanding the cause and correcting the problem will be essential for continued construction in earthquake-prone regions (Earth, 1994).

Geographic information systems (GIS) technology and Internet communications were the principal avenues of database and information management for the scientific response. Critical data—including maps and illustrations—were produced by digital means or converted to digital form. This information was then transmitted via the Internet to USGS investigators and to the broader public audience having Internet access (USGS, 2013).

3.3.2 Bam,Iran: December 26, 2003

On December 26, 2003 at 05:27 AM local time, an earthquake struck the Kerman province in southeastern Iran. The earthquake, according to the U.S. Geological Survey, measured 6.6 on the Richter scale, with its epicenter located near the city of Bam, 975 km southeast of Iran's capital of Tehran (Pranatio, 2003).

About 31,000 people killed, 30,000 injured, 75,600 homeless and 85 percent of buildings damaged or destroyed in the Bam area. Maximum intensities IX at Bam and VIII at Baravat. Felt (V) at Kerman. Damage estimated at 32.7 million U.S. dollars. Surface ruptures associated with the Bam Fault were observed between Bam and Baravat. Maximum acceleration of 0.98g recorded at Bam. Landslides occurred in the epicentral area. Believed to be the largest earthquake in this area in more than 2000 years (USGS Earthquakes, 2012).

To alleviate the sufferings of those people affected, the UN, in coordination with other government and humanitarian agencies has worked to provide the victims with basic daily necessities. Blankets, clothes, food, water, sanitation, medical aid, and tents were made available. These accommodations, however, are by no means sufficient. The tents provide little protection to the harsh desert climate which includes sandstorms, searing heat, and cold nights. The tents are also lacking sanitation facilities. With most medical facilities reduced to rubbles and half of the city's medical staff killed during the earthquake, the spread of diseases becomes a looming possibility. (Pranatio, 2003)

In May 2004, five months after the earthquake, temporary camps which are built with prefabricated technology have managed to house roughly 11% of the total population.(**Figure 3.8**) However, WHO reported that “most of the prefabricated houses are not well designed, as some of them have no kitchen facilities, latrines or showers” and that “with continuing ill environmental health, unsafe drinking water, inadequate access to curative care, and insufficient primary health care services, the situation in Bam is still in a state of emergency regarding health issues”. School and hospitals buildings have yet to be replaced. Rubbles still remain to be cleared out and progress on the reconstruction is slow. The United Nations has reported that it will take a minimum of 2 years and an estimate of \$ 1 billion to rebuild the city. In the meantime, the fates of the survivors remain uncertain (Pranatio, 2003).



Figure 3.8 : Temporary shelters,Bam.Iran (Corps, 2010)

Jan Egeland, United Nations humanitarian coordinator, stated: “A priority is shelter. People cannot continue to live in tents. We must get the water and sanitation systems working and we must provide people with an income” (Pranatio, 2003).

The loss brought by an occurrence of natural disaster is particularly high in countries with weak infrastructures, high population density, and inadequate emergency preparedness. As in the case of the Bam earthquake, traditional methods of providing emergency housing can often be insufficient. Tents offer little protection against harsh climates and while prefabricated housing offer more protection, most still lack the necessary electrical, gas, and plumbing utilities (Pranatio, 2003).

4. DISASTER MANAGEMENT CYCLE

Disasters have always been with people during the history and the human generations have always had to tolerate disaster and its caused damages. According to (ISDR, 2003) disaster is defined as:

“Serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Due to negative impacts of disaster on society and sustainable making an appropriate management of disaster is a necessity.

With this in mind, disaster management is defined as a cycle of activities including mitigation, preparedness, response and recovery. Mitigation efforts refer to those activities which reduce the vulnerability of society to the impacts of disasters. Preparedness efforts refer to those activities which make the government and disaster responders prepare for responding to a disaster, if it occurs. Response refers to the activities necessary to address the immediate and short-term effects of a disaster, which focus primarily on the actions necessary to save lives, to protect property and to meet basic human needs. Relief, rescue, search, firefighting, medical service, permit control, sheltering, evacuation, law enforcement and many others are samples of disaster response activities. Recovery efforts refer to those activities that bring communities back to normal (such as reconstruction) and they should be toward meeting mitigation and preparedness needs. **Figure 4.1** shows the cycle of disaster management in 4 sections: (Mansourian and others, 2006)

- Mitigation - Minimizing the effects of disaster. Examples: building codes and zoning; vulnerability analyses; public education.
- Preparedness - Planning how to respond. Examples: preparedness plans; emergency exercises/training; warning systems.
- Response - Efforts to minimize the hazards created by a disaster. Examples: search and rescue; emergency relief.
- Recovery - Returning the community to normal. Examples: temporary housing; grants; medical care (Khan H., Khan A., 2008).



Figure 4.1 : Cycle of Disaster Management

(Naghdi and others, 2008)

Depending on whether the event is predictable or unpredictable, the place of temporal sheltering in the cycle of disaster management will be different. If the disaster is predictable like the earthquake, sheltering the injured people is the major part after the disaster, which is a part of the response phase. In this situation for temporal sheltering of the injured people, the safe areas around the city or the countryside should be recognized as well as the rescue operations. In the next process, the injured people should be transferred to these safe areas by the optimum path, which is shown in **Figure 4.2**.

When the disaster is predictable like flood, sheltering the people will be explained in the preparation phase. In other word, people should be carried to safe areas by optimum path before the disaster occurrences. (Naghdi and others, 2006)

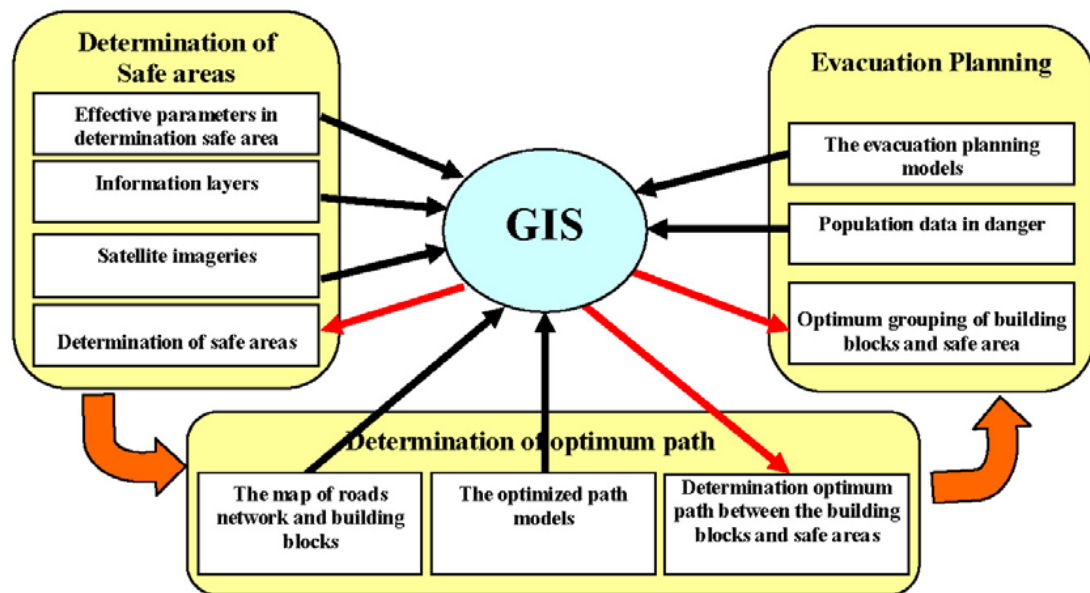


Figure 4.2 : The process of evacuation planning (Naghdi and others, 2008)

4.1 Before a Disaster (pre-disaster)

Pre-disaster activities those which are taken to reduce human and property losses caused by a potential hazard. For example, carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level, etc. Such risk reduction measures taken under this stage are termed as mitigation and preparedness activities (Warfield, 2008).

4.2 During a Disaster (disaster occurrence).

These include initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called emergency response activities (Warfield, 2008)

4.3 After a Disaster (post-disaster).

There are initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as response and recovery activities. Some of these cut across both stages (such things as coordination and the provision of ongoing assistance); whilst other activities are unique to each stage (e.g. Early Warning and Evacuation

during Emergency Response; and Reconstruction and Economic and Social Recovery as part of Recovery) (Warfield, 2008).

Disaster management aims to reduce, or avoid the potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery (Warfield, 2008).

The disaster management cycle illustrates the ongoing process by which governments, businesses, and civil society plan for and reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability or the prevention of disasters during the next iteration of the cycle. The complete disaster management cycle includes the shaping of public policies and plans that either modify the causes of disasters or mitigate their effects on people, property, and infrastructure. The mitigation and preparedness phases occur as disaster management improvements are made in anticipation of a disaster event. Developmental considerations play a key role in contributing to the mitigation and preparation of a community to effectively confront a disaster. As a disaster occurs, disaster management actors, in particular humanitarian organizations become involved in the immediate response and long-term recovery phases. The four disaster management phases illustrated here do not always, or even generally, occur in isolation or in this precise order. Often phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster (Warfield, 2008).

4.3.1 Post disaster response

Disaster response is the sum total of actions taken by people and institutions in the face of disaster. These actions commenced with the warning of an oncoming threatening event or with the event itself if it occurs without warning. (Mitchell, 2013).

The focus in the response and recovery phases of the disaster management cycle is on meeting the basic needs of the people until more permanent and sustainable solutions can be found. (Carrillo, 2010).

5. SHELTERS

Shelter is likely to be one of the most important determinants of general living conditions and is often one of the significant items of non-recurring expenditure. While the basic need for shelter is similar in most emergencies, such considerations as the kind of housing needed, what materials and design to be used, who constructs the housing and how long it must last will differ significantly in each situation. (UN, 2007)

When locating or planning emergency settlements, their long-term economic, social and environmental impacts on the surrounding area should be carefully considered. (Wisner B., Adams J., 2003)

In many situations, such as in northern Iraq and several countries of Eastern Europe and the former Soviet Union during the 1990s, people may independently seek shelter in buildings such as schools, community centers, offices, sports facilities, and even railway carriages and wagons. Such buildings are often also used for organized short-term evacuation centers. (Wisner B., Adams J., 2003)

Buildings used as short-term reception areas should be thoroughly inspected by a suitably qualified person, to ensure that they are not structurally damaged, or sited near potential secondary hazards. (Wisner B., Adams J., 2003)

5.1 Shelter Area Literature Review

Looking back to other worldwide studies about shelter site selection based on AHP there are some studies like:

GIS-Based Design of Urban Emergency Shelter in Songbei Harbin, which is about Songbei district of Harbin city as study area and flood damage as researching object, GIS spatial analysis is used to suitability analysis of emergency shelter by AHP getting every weight coefficient, which select drainage landscape function area, Songbei residential area and dam as main impacting factors. Finally, it determines three level emergency shelter alternative districts, community level, street level and urban district level. (Tong and others, 2012)

Comprehensive Evaluation Index System in the Application for Earthquake Emergency Shelter Site, which is aimed to establish earthquake emergency shelter site evaluation index system, make use of analytic hierarchy process method to determine

the index weight, using comprehensive fuzzy evaluation method to evaluate and order the shelters in certain areas, and ultimately select earthquake emergency shelters. (Chu Y.J, Su Y.P., 2010)

5.2 Criteria for Shelter Site Selection

5.2.1 Water

The single most important site-selection criterion is the availability of an adequate amount of water on a year round basis. This most important factor is also commonly the most problematic. A site should not be selected on the assumption that water can be acquired merely by drilling, digging, or hauling. Drilling may not be feasible and may not provide adequate water. No site should be selected where the hauling of water availability should be required over a long period. A professional assessment of water availability should be a prerequisite in selecting a site (OFDA, 1998).

Where water is readily available, drainage is a key criterion. For effective drainage, the entire site should be located above flood level at a minimum of 3 m above the water table, preferably on a gently sloping area. Flat sites can present serious problems for the drainage of waste and storm water. Marshes or areas likely to become marshy or soggy during the rainy season should be avoided. Conditions within the watershed may be a consideration (OFDA, 1998).

5.2.2 Open space

The site must provide a sufficient amount of usable space for the displaced population to engage in communal and agricultural activities, livestock husbandry, or other activities (e.g., recreation, meeting spaces, etc.). Although camp planning should be based on a known design capacity (e.g., shelter and other facilities sufficient for, say, 20,000 people), the possibility always exists that more people may arrive. To the extent possible, the site should be planned to accommodate a major influx of additional people. If the population has been displaced because of civil strife, the site should be removed from areas of potential conflict (OFDA, 1998).

5.2.3 Accessibility

The site must be accessible by vehicles and close to communication links and sources of supplies and services such as food, cooking fuel, shelter material, and national community services. (OFDA, 1998).

5.2.4 Land Rights

The land should be exempt from ownership, grazing, and other uses by local populations. Using such land can be a cause of local resentment. Authorities proposing the site may be unaware of customary rights exercised by local populations. Sites are often provided on public land by the government. Any use of the land must be based on formal legal arrangements in accordance with the laws of the country (OFDA, 1998).

5.2.5 Surface Area

The site must allow sufficient usable space for the refugees. WHO recommends 30 sq. meters plus the necessary land for the agricultural activities and livestock. More refugees may arrive and it is essential that the site allows for a major expansion beyond the area theoretically required for present numbers. It is particularly important that having allowed space for expansion, this is safeguarded until really needed. Otherwise the initial settlement will occupy all the space, and major upheavals of existing arrangements will be necessary as more refugees arrive (UN, 2007)

5.2.6 Topography and drainage

The whole site should be located above the flood level preferably on a gently sloping area. Flat sites can present serious problems for the drainage of waste and storm water. The watershed of the area itself will be a consideration (UN, 2007). for temporary planned camps the site gradient should not exceed 6%, unless extensive drainage and erosion control measures are taken, or be less than 1% to provide for adequate drainage. Drainage channels may still be required to minimise flooding or ponding. The lowest point of the site should be not less than 3 metres above the estimated level of the water table in the rainy season. Ground conditions should also inform the locations of toilets and other facilities and hence the planning of settlements e.g. fissured rock may disperse toilet waste widely; fine clays provide poor percolation and

the early failure of toilet pits; volcanic rock makes the excavation of toilet pits difficult. (Oxfam GB, 2004)

5.3 Standards

In addition to meeting the immediate needs, planning should take into consideration the long-term provision of services even if the situation is expected to be temporary. (UN, 2007)

Decisions on site selection and camp planning are very difficult to reverse, therefore seek technical support, for example avoiding high population density congestion in settlements and in accommodation; avoid very large settlements; refugee camps should normally be considered as the last option, involving refugees in all phases of settlement layout and shelter design and construction. (UN, 2007)

Use a bottom-up planning approach, beginning with the smallest social units, preserving traditional social arrangements and structures as far as possible. (UN, 2007)

Develop a comprehensive master plan with a layout based on open community structures and for the provision of community services, such as water points, latrines, showers, cloth-washing facilities and garbage collection in such a way as to promote ownership and maintenance of the services (UN, 2007).

When establishing post-disaster shelter recovery and reconstruction operations, site selection is the most consequential decision that must be made. No other decision has as profound and lasting an impact on the lives of victims or on the likelihood of long-term project success and sustainability. (Haddow G., Copolla D., 2010)

When a site assessment determines that relocation is the only or best option, government must first identify and secure viable land, and then undertake what amounts to a comprehensive yet accelerated (urban or rural) development-planning effort. (Haddow G., Copolla D., 2010)

Relocation site suitability assessments are conducted to assess hazard risk, environmental impact, topography, geology, hydrology, soil structure, and several other factors in order to determine the best location and layout of structures, and the housing design and construction materials to ensure safety and sustainability. (Haddow G., Copolla D., 2010)

The development and provision of standard site selection criteria, which dictates assessment processes and suitability decisions, will increase speed and efficiency of site selection and reduce variance among implementing agencies' efforts. (Haddow G., Copolla D., 2010)

Site selection needs to consider not only the viability of the individual home, but also how construction on that site will subsequently affect the community as a whole (including how the site will impact infrastructure access and recovery decisions). (Benson, Consulting, 2011)

Long-term housing reconstruction plans will need to consider a menu of possible options given the differences in each community's and each household's circumstances. (U. S. Department of Homeland Security, 2009)

Site selection should focus on keeping recipients as close to their land as is possible given risk reduction goals. (Benson CH, Twigg J, Rossetto T, 2007)

5.3.1 Standards for shelters

When existing buildings are not available, one possibility is to use tents or make shift shelters made of plastic sheets, tarpaulins, or local materials, such as palm thatch, in a secure location where water, sanitation and food can be provided. Emergency settlements for refugees and displaced people need to be established rapidly. However, they may be in service for months or even years, and it is usually impossible to know at the outset of an emergency how long the emergency settlement will exist. Therefore, the measures listed below are designed to provide healthy living conditions for disaster-affected people in both the short term and the long term. Specific long-term issues are discussed in Section 6.5. The requirements that ensure that temporary camps are healthy environments are considered below. (Oxfam GB, 2004)

The site should be free of major water-related hazards such as malaria, onchocerciasis (river blindness), schistosomiasis (bilharzia) and trypanosomiasis (sleeping sickness). If these diseases are endemic, care should be taken to avoid or control vector habitats and provide personal protection against mosquitoes, blackflies, tsetse flies, etc. (Oxfam GB, 2004)

The topography of the land should permit easy drainage and the site should be located above flood level. Rocky, impermeable soil should be avoided. Land covered with grass will prevent dust, but bushes and excessive vegetation can harbour insects, rodents, reptiles, etc., and should be avoided or cleared. Wherever possible, steep slopes, narrow valleys, and ravines should be avoided. Ideally, the site should have a slope of 2–4% for good drainage, and not more than 10% to avoid erosion and the need for expensive earth-moving for roads and building construction. (Oxfam GB, 2004)

Areas adjacent to commercial and industrial zones, exposed to noise, odours, air pollution and other nuisances should be avoided. (Oxfam GB, 2004)

Areas sufficiently close to blocks or rows of shelters should be identified for sanitation and waste management. The residential area of the camp should face the prevailing wind to avoid odours from latrines. (Oxfam GB, 2004)

There should be ample space for the people to be sheltered and for all the necessary public facilities such as roads, firebreaks (areas without buildings and with little or no flammable vegetation) and service areas (30m² per person, or 45m² per person allowing for small gardens, but not for full-scale agricultural activities). Areas for public spaces, markets, etc. should be defined from the beginning. (Oxfam GB, 2004)

To facilitate the management and control of communicable diseases, camps should hold no more than 10000–12000 people, or should be subdivided into independent units of no more than 1000 people. (Oxfam GB, 2004)

Drainage ditches should be dug around the tents or other shelters and along the sides of roads, especially if there is a danger of flooding. Care should be taken to lead water away from shelters, latrines, health centres, and stores. Persistent areas of stagnant water that are difficult to drain can be backfilled, or covered with polystyrene balls or a thin layer of oil, to control insects. Water points should also have adequate drainage to avoid mud. (Oxfam GB, 2004)

The site should be provided with at least two access roads for reasons of security and to reduce the risk of the site being cut off due to floods or other problems with roads. (Oxfam GB, 2004)

There should be a minimum of 3.5m² per person inside the shelter in warm climates where cooking is done outside, and 4.5–5.5m² per person in cold climates where cooking is done inside the shelter. (Oxfam GB, 2004)

The site chosen should be within reasonable distance of an ample source of good water and, ideally, near some high ground from which water can be distributed by gravity; water sources should gradually be improved and protected once basic needs are satisfied. No one should have to walk more than 500 metres to a water point, and there should be at least one water point for every 250 people. (Oxfam GB, 2004)

Where there is no piped water, water tanks should be installed on both sides of the road. (Oxfam GB, 2004)

More standards about buildings standards which are used as a shelter and shelter sites are mentioned in Appendix B and C.

5.4 Longer-term Issues For Emergency Settlements

When emergency settlements exist for more than a few weeks, a number of social, environmental and health issues need to be considered to ensure that the health and wellbeing of the settlement population are sustained and that long-term costs of maintaining the settlement infrastructure and services are kept under control. Some of the short term risks to health may be managed during the emergency phase, but when communities are obliged to remain in emergency settlements for a long time, a number of psychosocial and other health problems associated with alienation, overcrowding, and loss of control and purpose, demand special attention (Oxfam GB, 2004).

Longer-term settlements need more sustainable and durable water-supply and waste disposal systems, laundries and wastewater facilities. The need for recreational facilities may become greater. The safety of areas where children play must be ensured. If a stream or lake offers the opportunity for swimming or water sports, community volunteers should act as lifeguards (Oxfam GB, 2004).

More standards about buildings standards which are used as a shelter and shelter sites are mentioned in Appendix B and C.

6. GEOGRAPHIC INFORMATION SYSTEM (GIS)

Geographic Information Systems are information systems capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations (Carrillo, 2010).

6.1 GIS and the Disaster Management Cycle

6.1.1 Planning

The most critical stage of disaster management is the realization that there is a need for planning based on the risk that is present. The extent to which lives and properties will be spared the adverse effects of a disaster is dependent on the level of planning that takes place and the extent to which technology has been incorporated in planning efforts. GIS is useful in helping with forward planning. It provides the framework for planners and disaster managers to view spatial data by way of computer based maps (Carrillo, 2010).

6.1.2 Mitigation

The use of GIS in disaster management can help with structural and non-structural mitigation. GIS allows you to spatially represent areas at risk and the level of risk associated with particular hazard, which can be a guide in decision making. It will facilitate the implementation of necessary mechanisms to lessen the impact of potential emergency (Carrillo, 2010).

With GIS, disaster managers are in a better position to determine the level of mitigative structures that should be in place given the vulnerability of an area or population (Carrillo, 2010).

6.1.3 Preparedness

As a tool, GIS can help with the identification and location of resources and “at risk” areas. It establishes a link between partners and critical agencies, which allow disaster managers to know where relevant partner agencies are stationed. In the context of disaster management, GIS maps can provide information on the human resources

present in an Emergency Operation Centre as well as on the ground personnel such as security, health providers and other key responders. This is particularly useful since the technology can help with strategic placement of emergency personnel where it matters most. GIS helps to answer the question of who is to be based where and at what phase during the emergency. It can help to determine whether or not road infrastructure and communications networks are capable of handling the effects of disaster and, if necessary, guide in the placement of resources (Carrillo, 2010).

6.1.4 Response

GIS technology can provide the user with accurate information on the exact location of an emergency situation. This would prove useful as less time is spent trying to determine where the trouble areas are. Ideally, GIS technology can help to provide quick response to an affected area once issues (such as routes to the area) are known. In the case of a chlorine explosion for example, GIS can indicate the unsafe area as well as point rescue workers to resources that are closest to the affected areas. GIS can be used as a floor guide for emergency response to point out evacuation routes, assembly points and other evacuation matters (Carrillo, 2010).

6.1.5 Recovery

Mapping and geo-spatial data will provide a comprehensive display on the level of damage or disruption that was sustained as a result of the emergency. GIS can provide a synopsis of what has been damaged, where, and the number of persons or institutions that were affected. This kind of information is quite useful to the recovery process (Carrillo, 2010).

6.2 ArcGIS Methods

6.2.1 Near analyse

Determines the distance from each feature in the input features to the nearest feature in the near features, as is shown in **Figure 6.1**. (Esri, 2013)

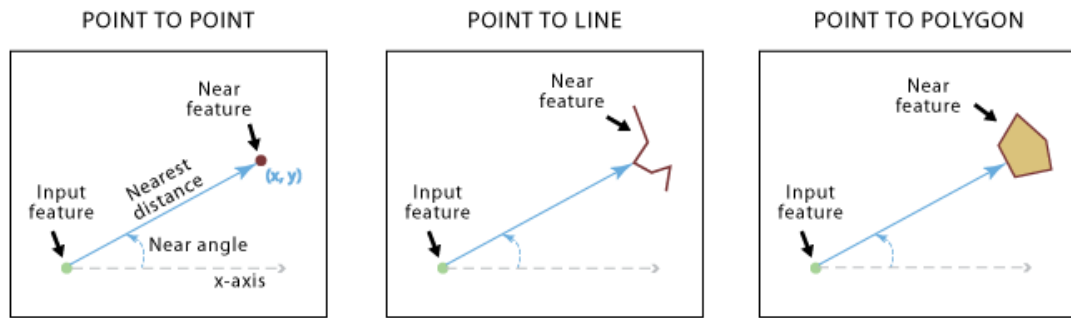


Figure 6.1 : Near analysis illustration (Esri, 2013)

The following sections go through the process of near analyse:

1. From Arc toolbox → Analysis tools → proximity → Near
2. In the opened window like **Figure 6.2**, in input feature part, the base map, and in near features, features which their distances from the base feature is going to be calculated should be selected.
3. By clicking ok all the distances will be calculated and it may take a long time like some hours in cases like roads map because of their huge amount of data.

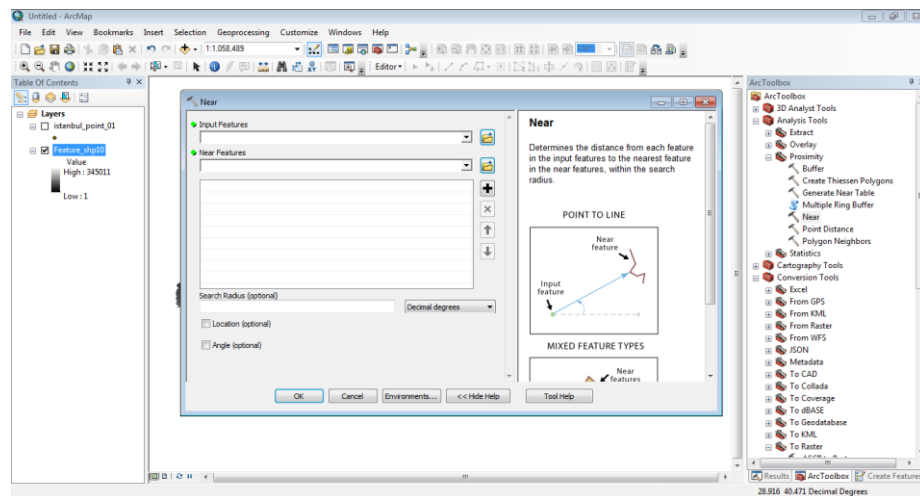


Figure 6.2 : Near analyse

6.2.2 Feature to raster

Any feature class (geodatabase, shapefile or coverage) containing point, line, or polygon features can be converted to a raster dataset. (Esri, 2013)

This tool always uses the cell center to decide the value of a raster pixel. This tool is a complement to the Raster to Point, Raster to Polyline, and Raster to Polygon tools, which convert a raster to different types of feature dataset geometries. (Esri, 2013)

The following sections go through the process of converting vector data to raster, and then carrying out analysis on this data.

1. Start ArcMap up
2. Click the Add Data button, and choose a file which contains vector data.
3. From Arc toolbox→conversion tools→to raster→feature to raster and a window like **Figure 6.3** will appear.

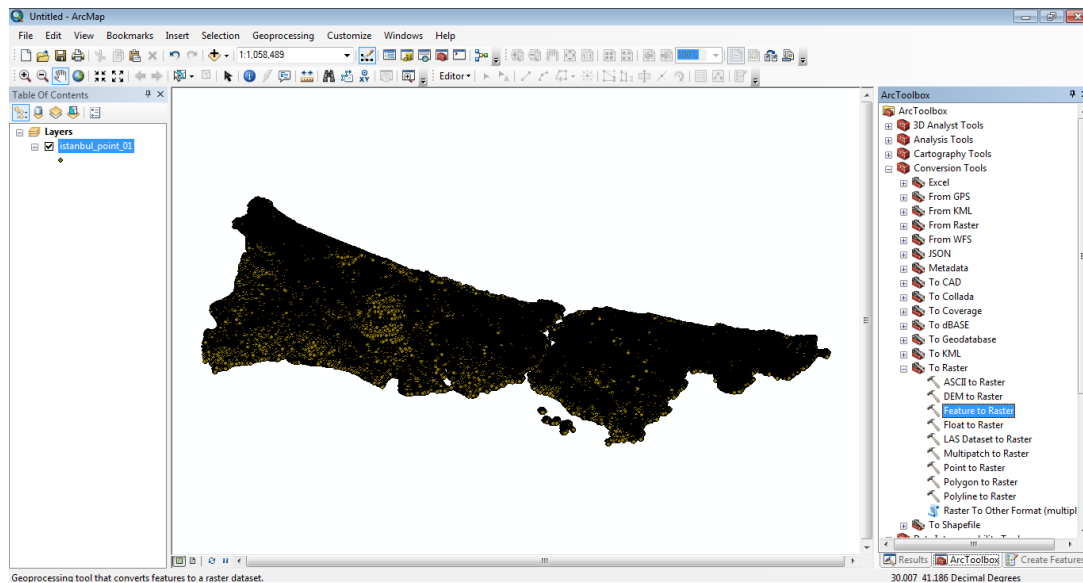


Figure 6.3 : Feature to raster conversion

4. In feature to raster windows choose the feature which is required to convert into raster as an input feature. →click ok
5. A feature layer will be provided as **Figure 6.4** :

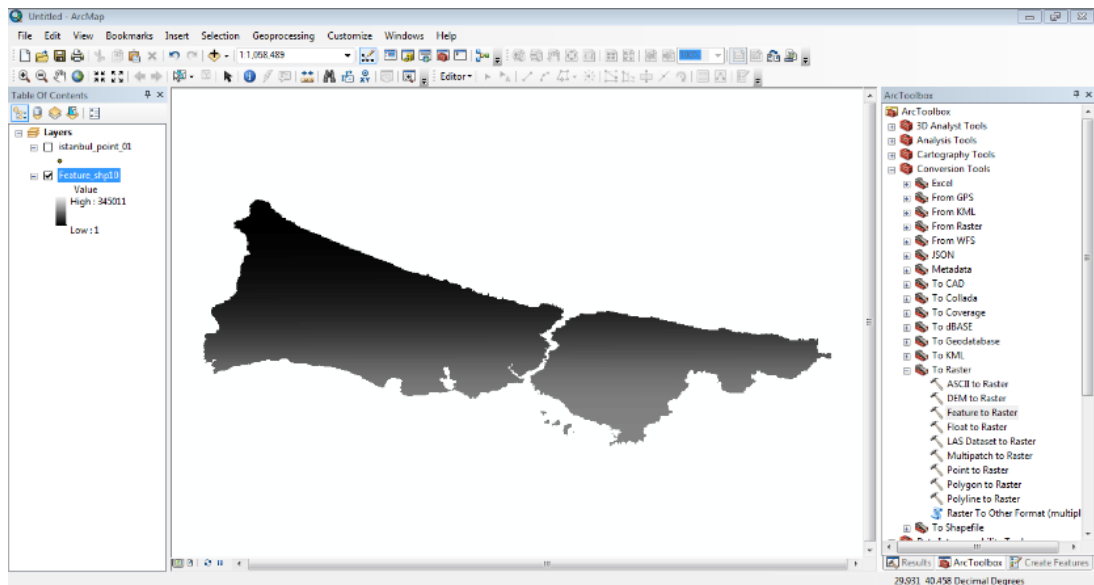


Figure 6.4 : Feature to raster result map

6.2.3 Classification

defining the class ranges and breaks-the high and low values that bracket each class-will determine which features fall into each class and thus what the map will look like. Changing the classes creates very different-looking maps. Generally,the goal is to make sure features with similar values are in the same class. (Minami, 1999)

Two key factors for classifying the data are the classification scheme which is used and the number of classes are created. If the data is wellknown, they could be manually defined by classes. (Minami, 1999)

Alternatively, ArcMap can classify the data using standard classification schemes. The four most common schemes are natural breaks, quantile, equal interval, and standard deviation. (Minami, 1999)

The following sections go through the classification method:

Layer properties → symbology

By choosing classify the classification method could be chosen from the opened window like **Figure 6.5** :

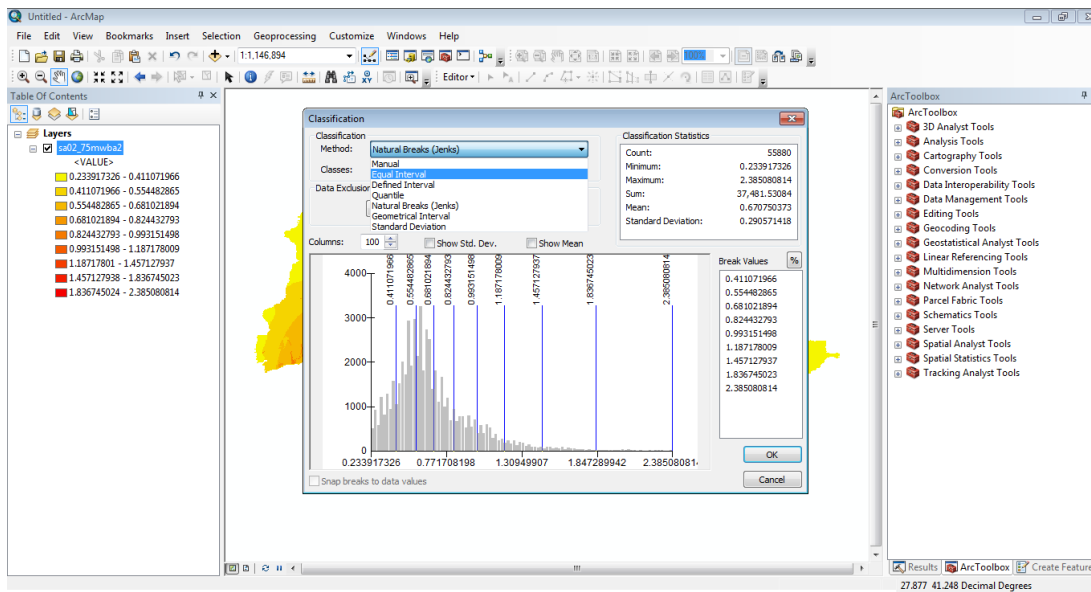


Figure 6.5 : Choosing classification method

Break values could be manually imported to specify the breaking points of histogram.

6.2.3.1 Standard classification schemes

6.2.3.1.1 Natural breaks (Jneks)

Classes are based on natural groupings of data values. ArcMap identifies break points by looking for groupings and patterns inherent in the data. The features are divided into classes as in **Figure 6.6** whose boundaries are set where there are relatively big jumps in the data values. (Minami, 1999)

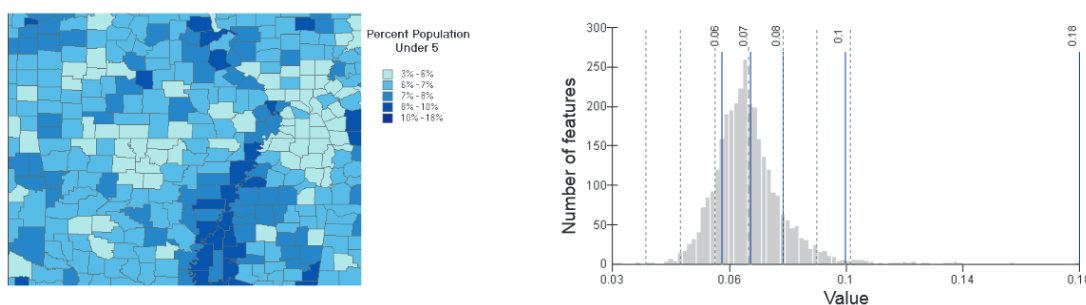


Figure 6.6 : Natural Breaks Classification (Minami, 1999)

6.2.3.1.2 Quantile

As in **Figure 6.7** Each class contains an equal number of features. A quantile classification is well suited to linearly distributed data. Because features are grouped by the number in each class, the resulting map can be misleading. Similar features can be placed in adjacent classes, or features with widely different values can be put in the

same class. This distortion could be minimized by increasing the number of classes (Minami, 1999)

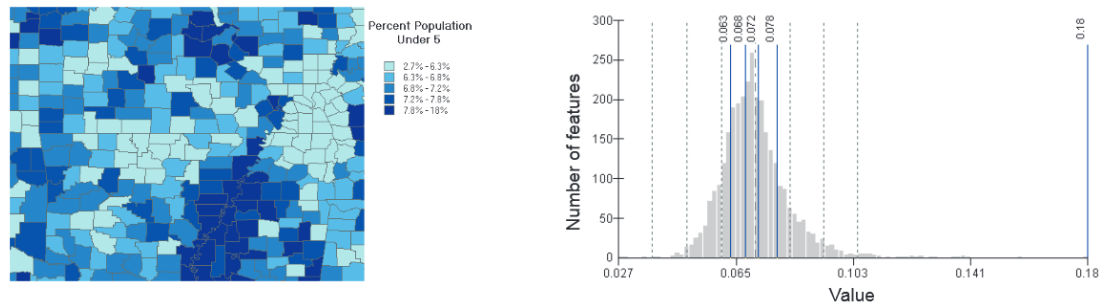


Figure 6.7 : Quantile Classification (Minami, 1999)

6.2.3.1.3 Equal interval

This classification scheme divides the range of attribute values into equal-sized subranges as in **Figure 6.8**. For example, if features have attribute values ranging from 0 to 300 and you have three classes, each class represents a range of 100 with class ranges of 0-100, 101-200, and 201-300. This method emphasizes the amount of an attribute value relative to other values, for example, to show that a store is part of the group of stores that made up the top one-third of all sales. It is best applied to familiar data ranges such as percentages and temperature. (Minami, 1999)

This method emphasizes the amount of an attribute value relative to other values. For example, it will show that a store is part of the group of stores that make up the top one-third of all sales. (Esri, 2014)

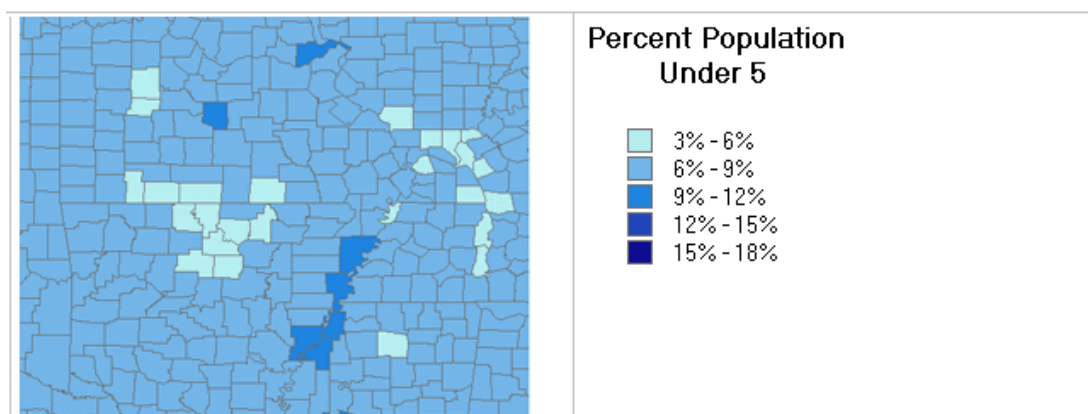


Figure 6.8 : Equal interval classification (Esri, 2014)

To set up an equal interval classification, set the classification method to Equal Interval and specify the number of classes as in **Figure 6.9** the number of classes is 6. (Esri, 2014)

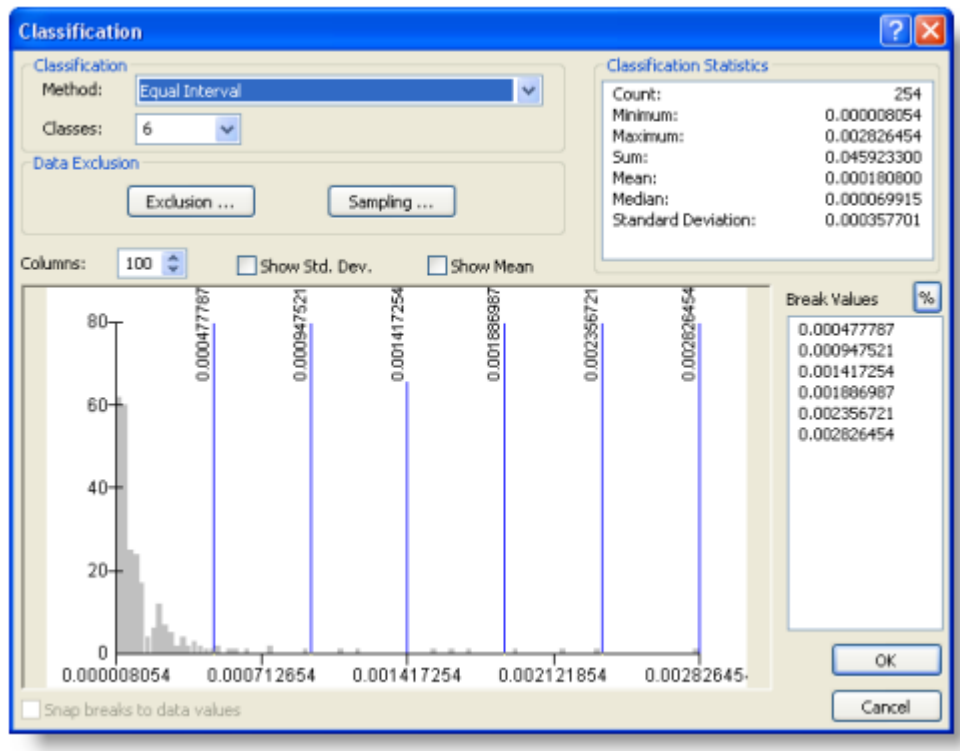


Figure 6.9 : Equal interval method (Esri, 2014)

6.2.3.1.4 Standard deviation

This classification scheme shows the amount a feature's attribute value varies from the mean. ArcMap calculates the mean value and then generates class breaks by successively adding to it or subtracting from it the standard deviation. A two-color ramp helps emphasize values above as in **Figure 6.10** (shown in blue) and below (shown in red) the mean. (Minami, 1999)

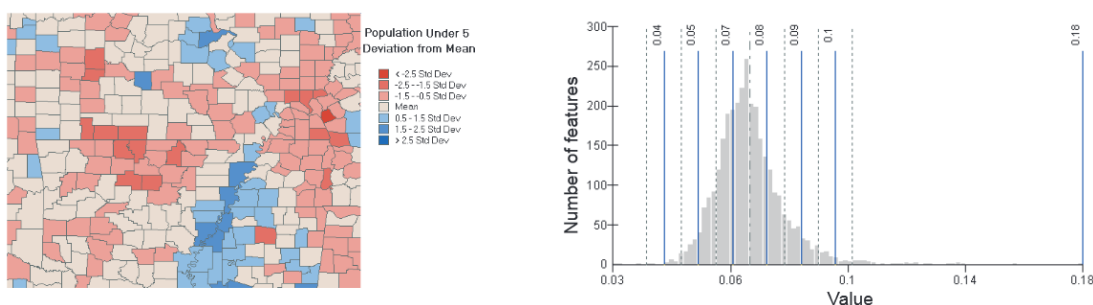


Figure 6.10 : Standard Deviation Classification (Minami, 1999)

6.2.3.2 Manual classification

To classify the classes manually, Class breaks could be added like **Figure 6.11** and it is possible to set the class ranges that are appropriate for data. Alternatively, it could start with one of the standard classifications and make adjustments as needed. (Esri, 2013)

There may already be certain standards or guidelines for mapping the data. For example, temperature maps are often displayed with 10-degree temperature bands, or possibly emphasize features with particular values, for example, those above or below a threshold value. (Esri, 2013)

Set the classification method to Manual, then click to set breaks and move class breaks. (Esri, 2013)

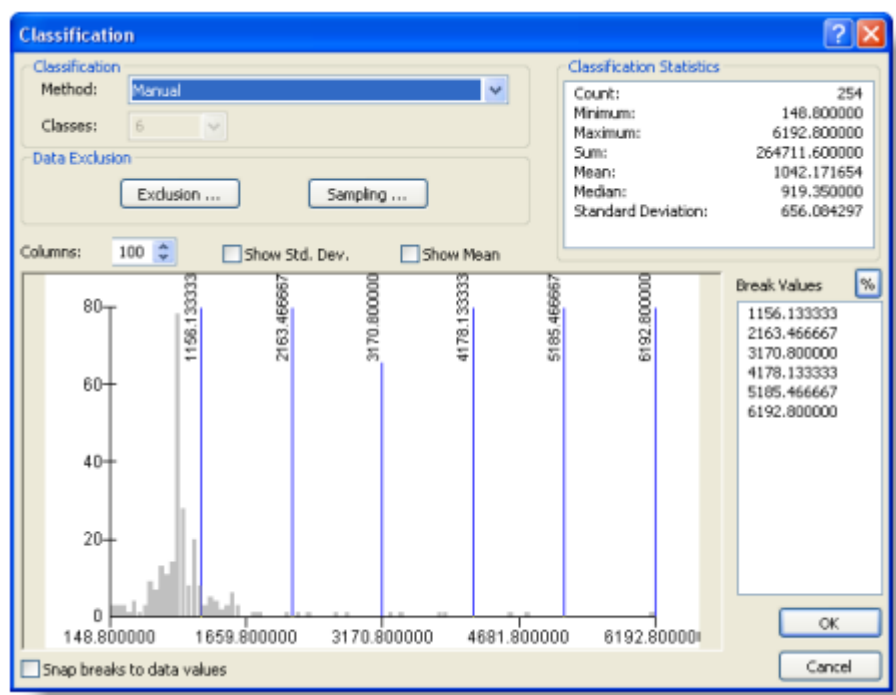


Figure 6.11 : Manual classification method (Esri, 2013)

Class break values could be manually highlighted and updated in the graph or enter values in the right-hand Break Values box. (Esri, 2013)

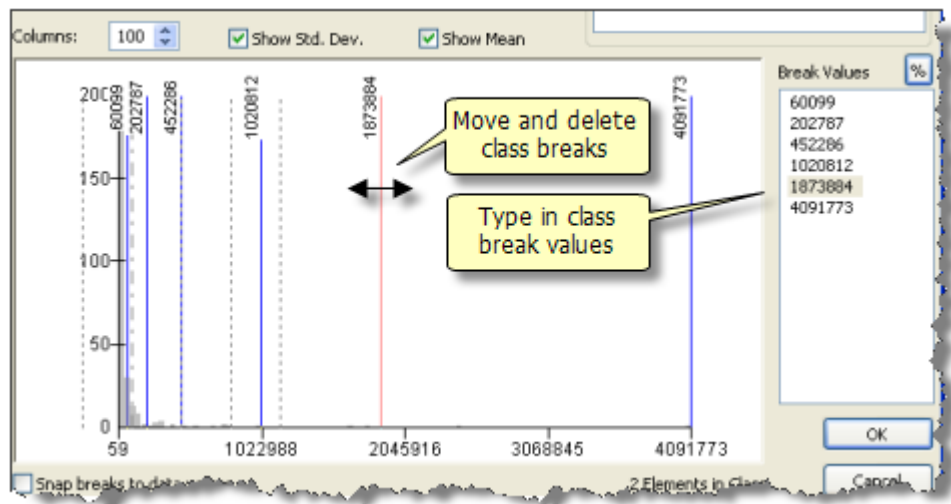


Figure 6.12 : Changing the break values (Esri, 2013)

In the right-hand panel in **Figure 6.12**, Percent button  in **Figure 6.13** makes it possible to work with the percentage of observations that fall in each class.

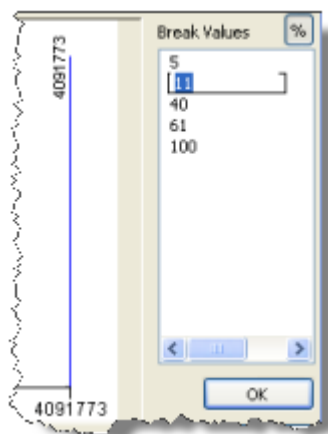


Figure 6.13 : Percent button (Esri, 2013)

6.2.4 Weighted sum

The Weighted Sum tool overlays several rasters, multiplying each by their given weight and summing them together and it is a useful way to add several rasters together is to input multiple rasters and set all weights equal to 1. The weight values can be any positive or negative decimal value. It is not restricted to a relative percentage or equal to 1.0. (Esri, 2014)

1. Add rasters.

2. Select the field.

3. Assign weights for input rasters.

4. Run the tool.

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6.2.4.1 Usage

- A useful way to add several rasters together is to input multiple rasters and set all weights equal to 1.
- Input rasters can be integer or floating point.
- The weight values can be any positive or negative decimal value. It is not restricted to a relative percentage or equal to 1.0.
- The weight will be applied to the specified field for the input raster. Fields can be of type short or long integer, double or float.
- By default, this tool will take advantage of multi-core processors. The maximum number of cores that can be utilized is limited to 4. (Esri, 2014)

6.2.5 Model-BUILDER

ModelBuilder is an application could be used to create, edit, and manage models. Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. ModelBuilder can also be thought of as a visual programming language for building workflows. (Esri, 2014)

While ModelBuilder is very useful for constructing and executing simple workflows, it also provides advanced methods for extending ArcGIS functionality by allowing to create and share models as tool. (Esri, 2014)

The benefits of ModelBuilder can be summarized as follows:

- ModelBuilder is an easy-to-use application for creating and running workflows containing a sequence of tools.
- You can create your own tools with ModelBuilder. Tools you create with ModelBuilder can be used in Python scripting and other models.
- ModelBuilder, along with scripting, is a way for you to integrate ArcGIS with other applications.
- ModelBuilder is how models and model tools are created. A model is nothing more than a sequence of tools and data chained together; the output of one tool

is fed to the input of another. When a model is saved, it becomes a model tool. (Esri, 2014)

As in **Figure 6.15** by opening ModelBuilder and clicking Geoprocessing > ModelBuilder , data and tools could be added to the ModelBuilder canvas by dragging them from the Catalog or Search window or by using the Add button . There are a variety of ways to connect data to tools; a common method is to use the Add Connection tool .

Once data is connected to tools, the model can be executed from within ModelBuilder by clicking the Run button . (Esri, 2014)

6.2.5.1 The ModelBuilder interface

ModelBuilder has a simple interface with drop-down menus, tools on a toolbar, and shortcut menu options as illustrated below. Shortcut menus are available for the whole model or any individual model element (variable, connector, or tool) with a right-click. The white empty space in a model onto which the tools are dragged and connected to the variables is called the canvas, whereas the appearance and layout of the tools and variables connected together is called the model diagram. (Esri, 2014)

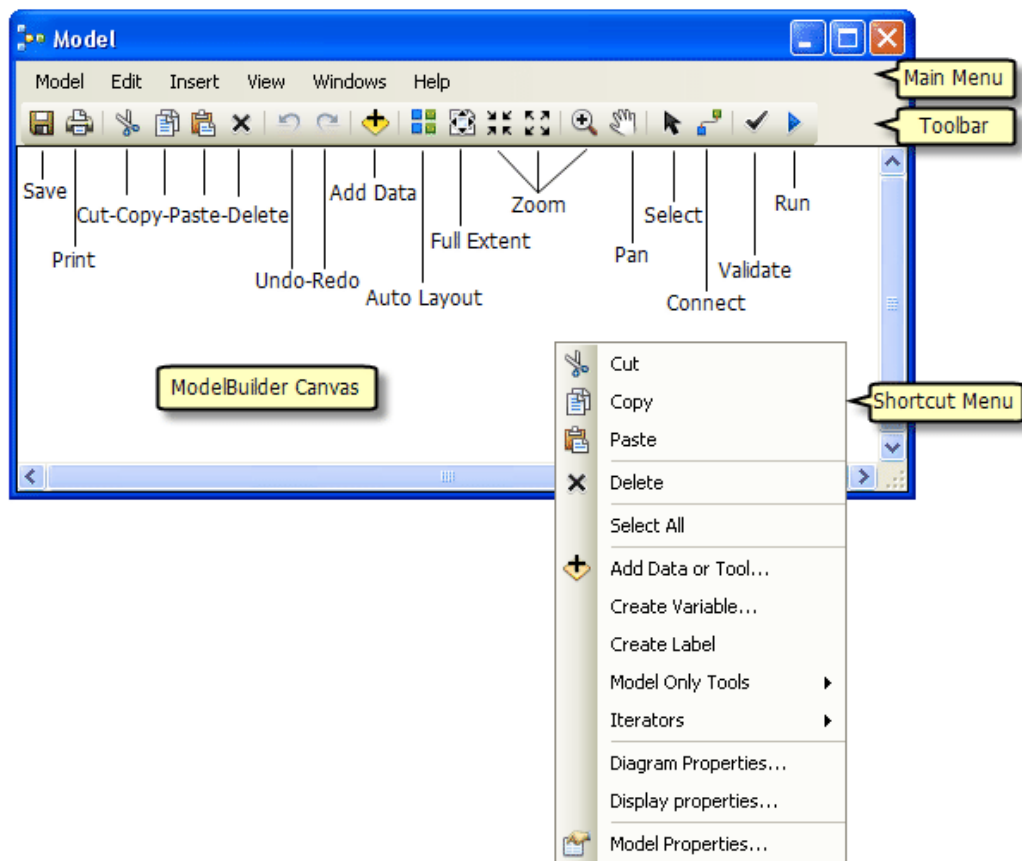


Figure 6.15 : Model Builder Interface (Esri, 2014)

7. ANALYTIC HIERARCHY PROCESS

7.1 Introduction

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by (Saaty T.L., 1977; Saaty T.L., 1994).

It is popular and widely used, in decision making and in a wide range of applications. Saaty, in his book, describes case applications ranging from the choice of a school his son, through to the planning of transportation systems for the Sudan. (International Hellenic University, 2012).

Analytic, the first word in AHP's name, is a form of the word analysis, which means separating a material or abstract entity into its constituent elements. Analysis is the opposite of synthesis, which involves putting together or combining parts into a whole. Because complex, crucial decision situations, or forecasts, or resource allocations often involve too many dimensions for humans to synthesize intuitively, we need a way to synthesize over many dimensions. High level corporate decisions meetings may have vice presidents of finance, marketing, operations, information systems, and human resources sitting around a conference table, each 'armed' with the results of analyses that their departments have performed. Each may also have reached a different conclusion as to what is best for the organization. The impasse usually is not because of a lack of good analyses, but a lack of ability to synthesize the analyses that have been made (Forman E.H., Gass S.I., 2001).

The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, subcriteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. Some of the industrial engineering applications of the AHP include its use in integrated

manufacturing in the evaluation of technology investment decisions, in flexible manufacturing systems, layout design and also in other engineering (Triantaphyllou E., Mann S.H., 1995).

To make a decision in an organised way to generate priorities we need to decompose the decision into the following steps.

1. Define the problem and determine the kind of knowledge sought.
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
3. Construct a set of pairwise comparison matrices. Each element in an upper Level is used to compare the elements in the level immediately below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained (TRF, 2008).

7.2 Chronological Development of AHP

In the late 1960's, Thomas Saaty, one of the pioneers of Operations Research, and author of the first Mathematical Methods of Operations Research textbook and the first queueing textbook, was directing research projects for the Arms Control and Disarmament Agency at the U.S. Department of State. Saaty's very generous budget allowed him to recruit some of the world's leading economists and game and utility theorists. In spite of the talents of the people Saaty recruited (three members of the team, Gerard Debreu, John Harsanyi, and Reinhard Selten, have since won the Nobel Prize), Saaty was disappointed in the results of the team's efforts. (Saaty T.L., 1996) later recalled:

“Two things stand out in my mind from that experience. The first is that the theories and models of the scientists were often too general and abstract to be adaptable to

particular weapon tradeoff needs. It was difficult for those who prepared the U.S. position to include their diverse concerns, and to come up with practical and sharp answers. The second is that the U.S. position was prepared by lawyers who had a great understanding of legal matters, but [who] were not better than the scientists in accessing the value of the weapon systems to be traded off.” (Forman E.H., Gass S.I., 2001).

Years later, while teaching at the Wharton School, Saaty was troubled by the communication difficulties he had observed between the scientists and lawyers and by the apparent lack of a practical systematic approach for priority setting and decision making (Forman E.H., Gass S.I., 2001).

Having seen the difficulty experienced by that the world’s best scientists and lawyers, Saaty was motivated to attempt to develop a simple way to help ordinary people make complex decisions. The result was the Analytic Hierarchy Process -- a synthesis of existing concepts that attests to Saaty’s genius through its power and simplicity (Forman E.H., Gass S.I., 2001).

There is ample evidence that the power and simplicity of AHP has led to a widespread acceptance and usage in the United States as well as throughout the world. In addition to Expert Choice, there have been several other successful commercial implementations of AHP, one with financial backing of the Canadian Government (Forman E.H., Gass S.I., 2001).

Many of the world’s leading information technology companies now use AHP in the form of decision models provided by the Gartner Group’s, Decision Drivers. The American Society for Testing and Materials (ASTM) has adopted AHP as a standard practice for multiattribute decision analysis of investments related to buildings and building systems. The AHP process is taught in numerous Universities and used extensively in organizations such as the Central Intelligence Agency that have carefully investigated AHP’s theoretical underpinnings (Forman E.H., Gass S.I., 2001).

7.3 Basic Principles

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the

criterion or property with respect to which they are compared. Figure 7.1 exhibits the scale. (TRF, 2008).

Table 7.1 : The fundamental scale of absolute numbers (TRF, 2008)

<i>Intensity of Importance</i>	<i>Definition</i>	<i>Explanation</i>
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j , then j has the reciprocal value when compared with i	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

The heart of his method, the Analytic Hierarchy Process, consists of the construction of pairwise comparison matrices and the extraction of weights by means of the principal right eigenvector. With a pairwise comparison matrix for n items the decision maker indicates how much more important (or how much more suitable, or how much better qualified, or whatever the basic comparison mode is) item i is than item j . The decision maker is explicitly required to make more pairwise comparisons than absolutely necessary. (Dijkstra, 2011).

The following is a simple decision examined by someone to determine what kind of job would be best for him/her after getting his/her PhD: either to work in two kinds of companies or to teach in two kinds of schools. The goal is to determine the kind of job for which he/she is best suited as spelled out by the criteria. Because of space limitations we will not define them in detail here. (TRF, 2008)

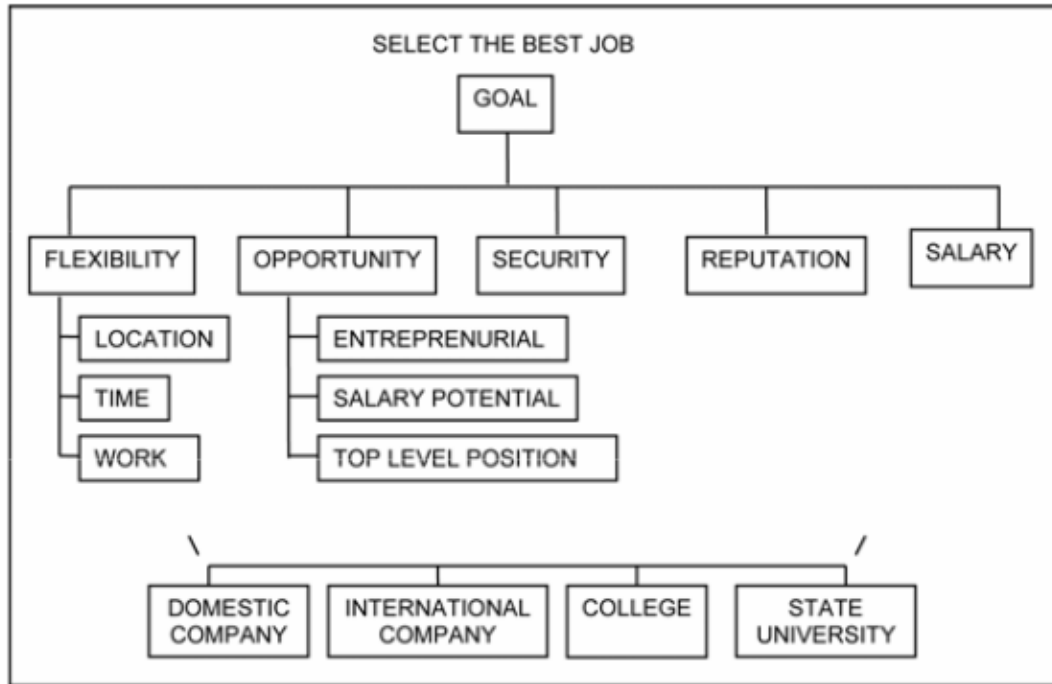


Figure 7.1 : Best job decision (TRF, 2008)

There are 12 pairwise comparison matrices in all: One for the criteria with respect to the goal, which is shown here in **Figure 7.1**, two for the subcriteria, the first of which for the subcriteria under flexibility: location, time and work, that is given in Figure 7.3 and one for the subcriteria under opportunity that is not shown here. Then, there are nine comparison matrices for the four alternatives with respect to all the ‘covering criteria’, the lowest level criteria or subcriteria connected to the alternatives. The 9 covering criteria are: flexibility of location, time and work, entrepreneurial company, possibility for salary increases and a top-level position, job security, reputation and salary. The first six are subcriteria in the second level and the last three are criteria from the first level. We only show one of these 9 matrices comparing the alternatives with respect to potential increase in salary in **Figure 7.2**. (TRF, 2008)

Pairwise comparison matrix of the main criteria with respect to the Goal

	<i>Flexibility</i>	<i>Opportunities</i>	<i>Security</i>	<i>Reputation</i>	<i>Salary</i>	<i>Priorities</i>
Flexibility	1	1/4	1/6	1/4	1/8	0.036
Opportunities	4	1	1/3	3	1/7	0.122
Security	6	3	1	4	1/2	0.262
Reputation	4	1/3	1/4	1	1/7	0.075
Salary	8	7	2	7	1	0.506

Figure 7.2:1. Pairwise comparison matrix of the main criteria with respect to the Goal (TRF, 2008)

Pairwise comparison matrix for the subcriteria with respect to flexibility

	<i>Location</i>	<i>Time</i>	<i>Work</i>	<i>Priorities</i>
Location	1	1/3	1/6	0.091
Time	3	1	1/4	0.218
Work	6	4	1	0.691

Pairwise comparison matrix for the alternatives with respect to potential increase in salary

	<i>Domestic Co</i>	<i>Int'l Co</i>	<i>College</i>	<i>State Univ.</i>	<i>Priorities</i>
Domestic company	1	4	3	6	0.555
Int'l company	1/4	1	3	5	0.258
College	1/3	1/3	1	2	0.124
State University	1/6	1/5	1/2	1	0.064

Figure 7.3: 2.pairwise comparison matrices for subcriteria (TRF, 2008)

The next step is the calculation of a list of relative weights, importance, or the value of the factors, such as salary or security. (International Hellenic University, 2012)

The final stage is to calculate a Consistency Ratio (CR) to measure how consistent the judgements have been relative to a large samples of purely random judgements. If the CR is much in excess of 0.1 the judgements are untrustworthy because they are too close to conform to randomness and the exercise is valueless or must be repeated. It is easy to make a minimum number of judgements after which the rest can be calculated to enforce a perhaps unrealistically perfect consistency. (International Hellenic University, 2012)

7.4 Theory

Consider n elements to be compared, $C_1 \dots C_n$ and denote the relative weight (or priority or significance) of C_i with respect to C_j by a_{ij} and form square matrix $A=(a_{ij})$ of order n with the constraints that $a_{ij}=1/a_{ji}$ for $i \neq j$, and $a_{ii}=1$, all i . Such a matrix is said to be a reciprocal matrix. The weights are consistent if they are transitive, that is $a_{ik}=a_{ij}.a_{jk}$ for all i, j and k . Such a matrix might exist if the a_{ij} are calculated from exactly measured data. Then find a vector w of order n such that $Aw=\lambda w$, for such a matrix w is said to be an eigenvalue. For a consistent matrix $\lambda=n$. For matrices involving human judgment, the condition $a_{ik}=a_{ij}.a_{jk}$ does not hold as human judgments are inconsistent to a greater or lesser degree. In such a case the w vector satisfies the equation $Aw=\lambda_{\max} w$ and $\lambda_{\max} \geq n$. The difference, if any, between $\lambda_{\max}$ and n is an indication of the inconsistency of the judgments. If $\lambda_{\max} = n$ then judgments

have turned out to be consistent. Finally a consistency index (CI) can be calculated from:

$$CI = (\lambda_{\max} - n) / (n - 1)$$

That needs to be assessed against judgments made completely at random and (Saaty, 2008) has calculated large samples of random matrices of increasing order and the Consistency Indices of those matrices. A true Consistency Ratio is calculated by dividing the Consistency Index for the set of judgments by the Index for the corresponding random matrix. (International Hellenic University, 2012)

$$CR = CI / RI$$

Table 7.2 : Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

(Saaty, 2008) suggests that if that ratio exceeds 0.1 the set of judgments may be too inconsistent to be reliable. In practice, CRs of more than 0.1 sometimes have to be accepted. Perfect consistency of judgments is indicated by a CR having value of 0.

8. APPLICATION

For multi-criteria Decision making there are 2 important features, first: Gathering the data, storage, application and related GIS analysis. The second one is Decision maker's application and making the multi-criteria decision with the spatial data.

Different methods were applied to each sub-criteria data to make them ready for analysis.

- Accessibility sub-criteria which were taken from Istanbul Metropolitan Municipality were all applied to Near analyse, then reclassified to 7 classes. After these steps weighted-sum analyse was applied to each map.
- Infrastructure sub-criteria which were obtained from Istanbul Metropolitan Municipality like Gas and Waste water were applied to Near analyse, reclassification and weighted-sum analyse.
- For communication data from GSM base station were used. Near analyse, reclassification and weighted sum were applied to the data of this map.
- For electricity all the data about underground and electric lines were merged and then been applied to near analyse.
- For Drinking water two maps of water lines and water-connections were merged together as water supplies. Like all the other maps for this data Near analyse, reclassification and weighted-sum analyse were applied.
- Hazard maps were prepared from different sources and in different and in some cases in complicated way. For all these map in classification section being far from these areas was considered as an advantage and had the biggest value.
- Earthquake hazard map was obtained from HAZTURK program, so there was no need to do the Near analyse. It was classified into 7 classes as the other maps.
- Tsunami hazard map was taken from Earthquake and Land analysis of Istanbul Metropolitan Municipality reclassification and also weighted-sum analyse were applied to this map.
- Flooding hazard map was a combination of flooding and rivers. Then it was applied to reclassification and weighted-sum analyse.

- Fire hazard map was taken from (Erden T., Coskun M.Z., 2012) study. Since it was for a specific part of Istanbul in reclassification section for the rest of Istanbul value of 1 was considered which means those areas are not suitable according to Fire risk. Weighted-sum analyse were applied to this map as other maps.
- Topography map was obtained from HAZTURK program. For classification all the values were applied manually form 1% slope to 30% slope.
- Land usage maps were obtained from 2 maps. Both of them were provided by Istanbul Metropolitan Municipality. For reclassification each class was given a value manually according to their suitability for a shelter site. For example parks had the most and forests and urban facilities had the less value in this classification.
- Capacity map was obtained from Landsat 8 satellite images which were taken on 30.07.2013. For the areas which had no data value of 1 was considered which means those areas have less propriety to be a shelter site.
- Also Istanbul-point map which was obtained from slop map and used as a base map for each sub-criteria to use in all analysis is shown in **Figure 8.1**.

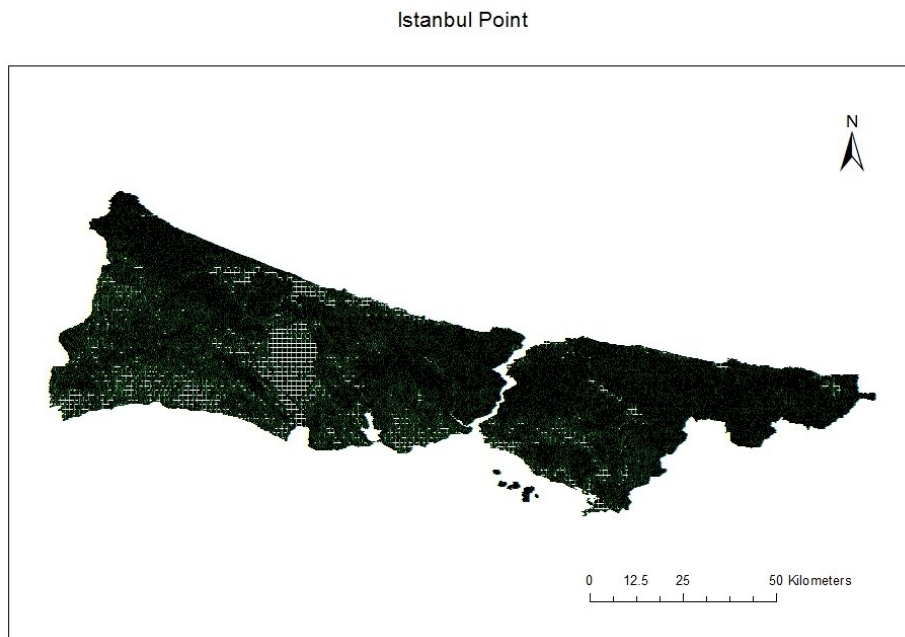


Figure 8.1 :Istanbul point map used as a base map

After Near analysis- which is explained in section 6.2.1- were applied to each map to calculate distance and additional proximity information between the input features(Istanbul point) and the closest feature in another layer or feature class (roads,railways,port merines...). All the maps were converted to Raster with Feature to Raster tool- which is explained in section 6.2.2- and the reason to do that is vector data can be displayed in a 3D view but cannot be used to describe the topography of other layers, And where features are broken up into individual cells, or pixels can be quite large, but offer a wide range of analysis options,

8.1 Importance of Each Criteria

The importance of each criteria was considered according to its weight after calculating from the questionnaires using pairwise comparison and analytical hierarchy process (Choo E.U., Schoner B., Wedley W.C., 1999) which obtained from the academics and students of Istanbul technical university and some Civil engineering and Geomatics engineering students who experienced the 2012 Varzeghan-Tabriz-Iran earthquake

8.2 Questionnaires for Criteria

Some questionnaires (**Figure 8.2**) according to pairwise comparison were provided about infrastructure, damage risk, accessibility, topology, land usage and the capacity of temporary shelter site and asked from the academics of Geomatics department, Earthquake engineering and disaster management department, mine engineering department and some of students of civil engineering and Geomatics engineering department which experienced the earthquake that occurred near the cities of Ahar and Varzeqan in Iran's east Azerbaijan province on August 11.2012, some of students of Geomatics department and other departments of Istanbul technical university (ITU). Also during another step some questionnaires were gathered from some associations as below:

Aile ve Sosyal Politikalar Bakanlığı - İstanbul Şubesi (ministry of family and social policies)

GEA : (Gesellschaft für Entstaubungsanlagen)

AKUT: Search and Rescue Association

MAG : Neighborhood Disaster Volunteers

İstanbul il AFAD Müdürlüğü : Istanbul prime ministry disaster & emergency management residency

Kızılay : Red cross

DASK : Turkish Catastrophe Insurance Pool

İstanbul İl Sağlık Müdürlüğü : Istanbul Provincial Directorate of Health

ODTÜ Sosyoloji : Middle-east Technical University – Social Science

BOĞAZİÇİ – EKONOMİ : Bosphorus University – Economical Science

KANDİLLİ : Kandilli Observatory

criterias	Pairwise Comparison																	Criteria
	Very very strong	Between very and very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Infrastructure (AL)																		ER
																		HG
																		TO
																		KA
																		AK
Accessibility (ER)																		HG
																		TO
																		KA
																		AK
Hazard (TH)																		TO
																		KA
																		AK
Topography (TO)																		KA
																		AK
Capacity (KA)																		AK
Name,Surname																		
Title																		
Profession																		

Figure 8.2 :Questionnaires about critesias using pairwise comparison

(Alt yapı: infrastructure : AL . Erişebilirlik: accessibility : ER . Tehlike: Hazard : TH.
Kapasite: capacity : KA . Arazi kullanım türü: land usage : AK)

8.3 Questionnaires for Sub Criteria:

Each criteria were divided to its sub-criteria as below; and for each criteria (infrastructure, damage risk and accessibility) a questionnaire was provided to obtain the weights of each criteria by using analytical hierarchy process in order to understand the importance of each sub criteria.

- Infrastructure (**Figure 8.3**) to : Communication infrastructure, Drinking water infrastructure, sewerage infrastructure, Electrical infrastructure and Gas infrastructure. (Communication infrastructure: iletişim : IL, Drinking water infrastructure : içme su SU, sewerage infrastructure: Kanalizasyon : KN, Electrical infrastructure: Elektrik : EL and Gas infrastructure: Gaz : GZ.)

Criteria	Pairwise Comparison Criterias																	Criteria
	Very very strong Between very and very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very strong	Very very strong		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
communication (IL)																		SU
																		KN
																		EL
																		GZ
Drinking water (SU)																		KN
																		EL
																		GZ
Sewerage (KN)																		EL
																		GZ
Electricity (EL)																		GZ
Name,surname																		
Tizle																		
Profession																		

Figure 8.3 :Questionnaire for sub criteria of infrastructure

- Hazard (**Figure 8.4**) to : Earthquake risk, Tsunami risk, Flooding risk, Fire risk and landslide risk.

Criterias	Pairwise Comparison Criteria																	Criteria
	Very very strong	Between very and very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Earthquake (DP)																		TS
																		HY
																		SB
																		KM
																		YN
Tsunami (TS)																		HY
																		SB
																		KM
																		YN
Landslide(HY)																		SB
																		KM
																		YN
Flooding(SB)																		KM
																		YN
Chemical (KM)																		YN
Name,surname																		
Title																		
Profession																		

Figure 8.4 : Questionnaire for sub criteria of Hazard

- Accessibility (**Figure 8.5**) to : Highways, Railways, Heliports and seaports.

<i>Criteria</i>	<i>Pairwise Comparison Criteria</i>																<i>Criteria</i>
	Very very strong	Between very and very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	
<i>Highways (KR)</i>																	<i>DN</i>
																	<i>HV</i>
																	<i>DM</i>
<i>Sea routes (DN)</i>																	<i>HV</i>
																	<i>DM</i>
<i>Helicopter (HV)</i>																	<i>DM</i>
<i>Name,surname</i>																	
<i>Title</i>																	
<i>Profession</i>																	

Figure 8.5 :Questionnaire for sub criteria of Accessibility

8.4 Calculating the Weights of Sub-criteria Using AHP:

The **Figure 8.6** is showing how to calculate the weights step by step from the questionnaires which were collected. All the answers were docket into an excel file and the calculation were applied to them according to AHP (analytical hierarchy process).

E2															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		Electrical Distribution System	Interior Gas System	Weights			Consistency Ratio	lambda	CI	CR					
2	Electrical Distribution System	1.000	3.000	0.750			1.5	2	2	0	#####	<0,1			
3	Interior Gas System	0.333	1.000	0.250			0.5	2							
4		1.333	4.000												
5															
6		0.750	0.750	0.750											
7		0.250	0.250	0.250											
8															
9															
10		Water Heater	Access to roads	Far from faults	Far from oceans	Far from industrial.Fac	Weights		Consistency Ratio	lambda	CI	CR			
11	Water Tanks	1.000	0.333	0.333	0.500	2.000	0.11077		0.55919	5.04837	5.10744	0.02686	0.02398	<0,1	
12	Access to roads	3.000	1.000	2.000	2.000	4.000	0.36669		1.8895	5.15283					
13	Far from faults	3.000	0.500	1.000	2.000	3.000	0.26460		1.36886	5.1734					
14	Far from oceans	2.000	0.500	0.500	1.000	3.000	0.18525		0.94051	5.07691					
15	Far from industrial.Fac	0.500	0.250	0.333	0.333	1.000	0.07269		0.3697	5.08569					
16		9.501	2.583	4.167	5.833	13.000									
17															
18		0.105	1/9.501	0.129	0.080	0.086	0.154	0.11077							
19		0.316	3/9.501	0.387	0.480	0.343	0.308	0.36669							
20		0.316		0.194	0.240	0.343	0.231	0.26460							
21		0.211		0.194	0.120	0.171	0.231	0.18525							
22		0.053		0.097	0.080	0.057	0.077	0.07269							

Figure 8.6 : Calculating the weights of each sub-criteria by using analytical hierarchy process

8.5 Classification Process

As explained in section 6.2.1, all the maps after applying Near Analyse on them and calculating each point of the vector map to Istanbul point map which is the base map for these applications, and after converting all the result map obtained from Near analyse to Raster which is explained in details in section 6.2.2 -except the maps which were already Raster data- should be classified which the method is explained in section 6.2.3.

In cartographic representation it is suggested that tone scale should not include more than seven tone values. (Erden T., Karaman H., 2012) **Figure 8.7** shows the classification of Electricity network of Istanbul.

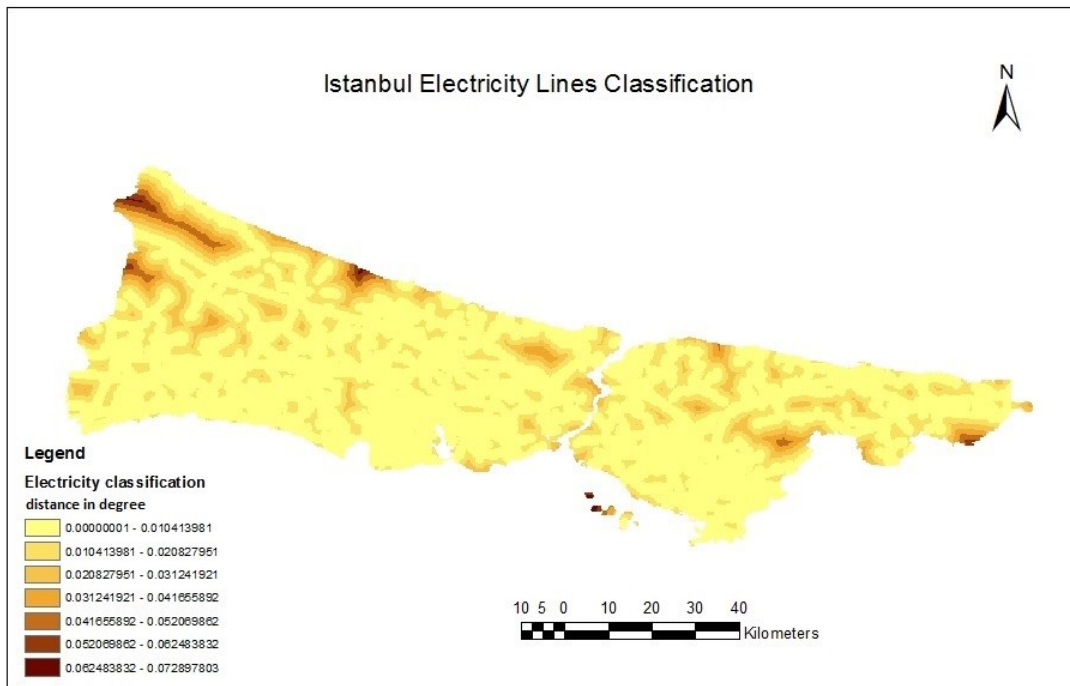


Figure 8.7 : Istanbul Electricity Lines Classification

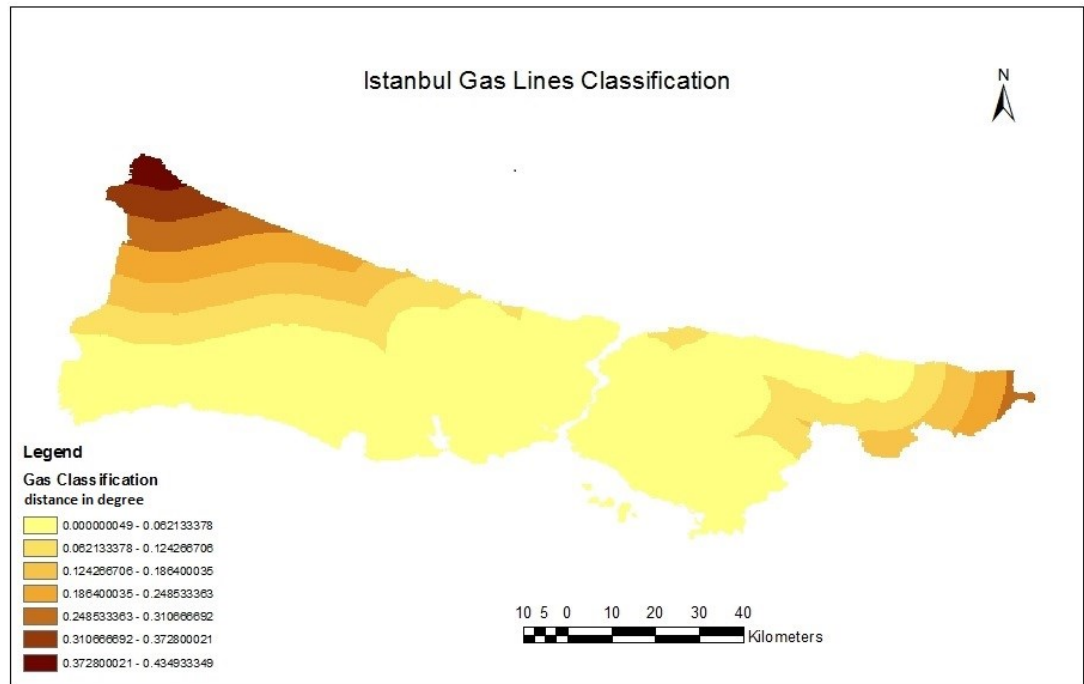


Figure 8.8 : Istanbul Gas Lines Classification

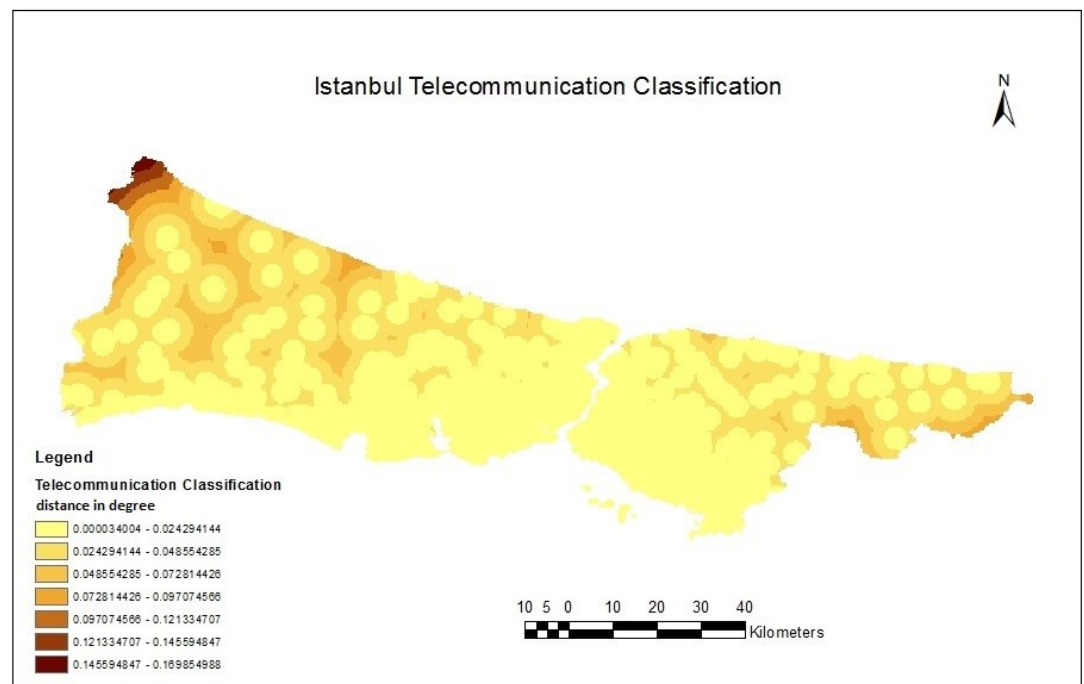


Figure 8.9 : Istanbul GSM base stations Classification

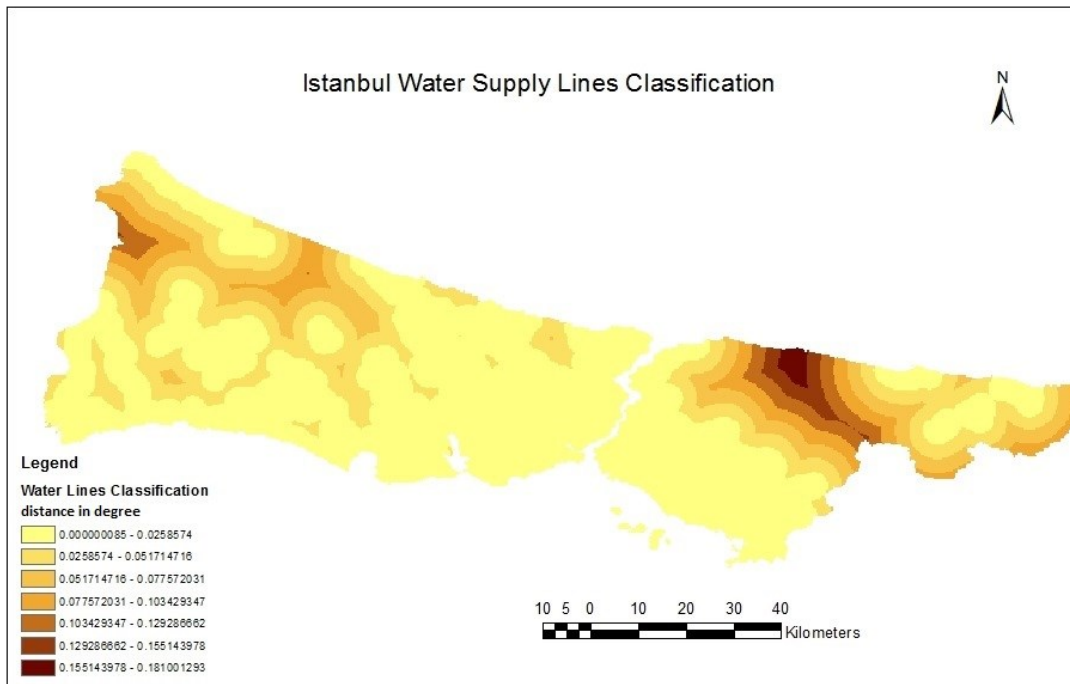


Figure 8.10 : Istanbul Water Supply Classification

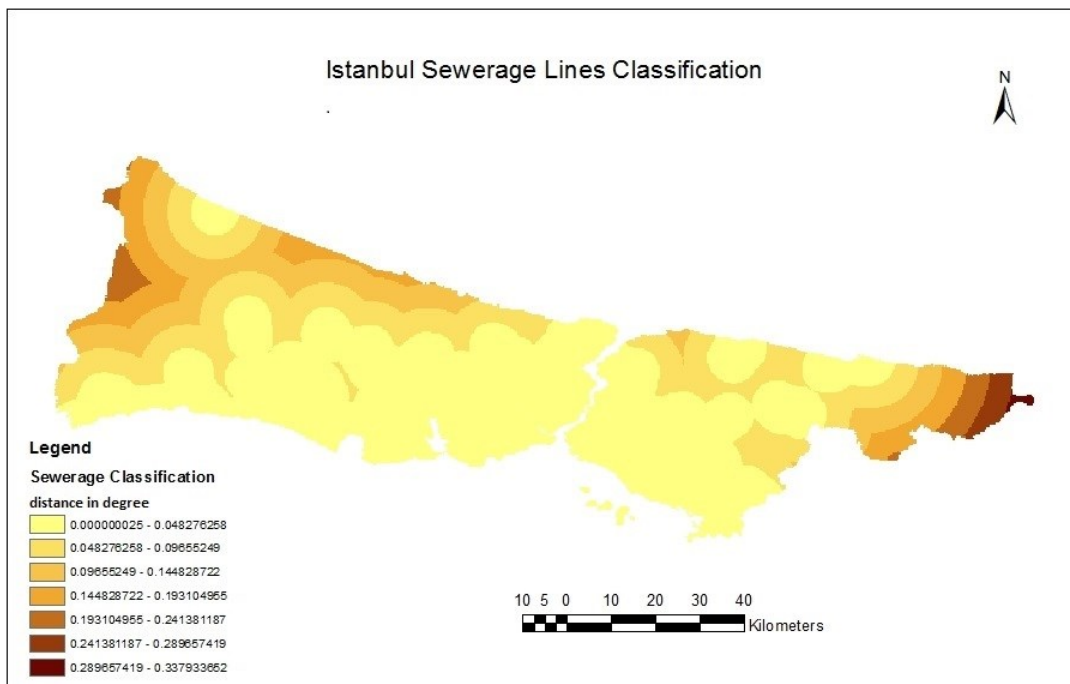


Figure 8.11 : Istanbul Sewerage Lines Classification

8.6 Weighted Sum Process

All weights which were obtained from calculations in section 8.5 were applied to maps in order to gain a result map that shows the importance of each sub-criteria and criteria. In the opened window in **Figure 8.12** as input raster enter each raster data and import their weights according to the calculations from AHP.

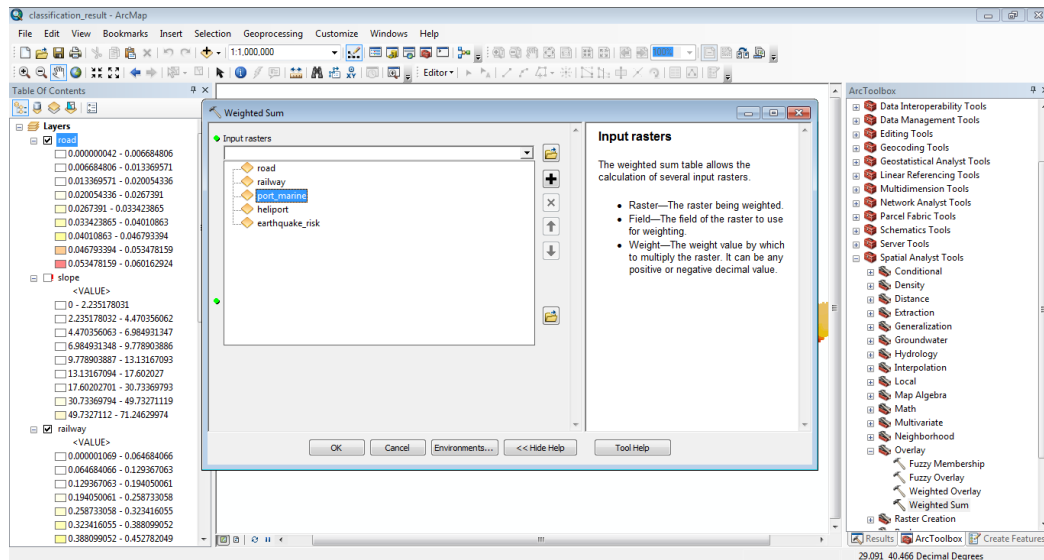


Figure 8.12 : Applying Weighted sum

8.7 Building the Model of the Study

The next and last step of this study was building a model with data which were prepared in pervious sections. As mentioned in section 6.2.5.1 the model was built by the model builder tool in Geoprocessing toolbar. All the data were added to model as raster data as **Figure 8.13**, some of them were after classification and some without classification, for example for infrastructure data an extra step was added as classification but for example for hazard data it was not necessary beacause the data itself was classified and only weighted sum analyse was required to apply to data . So all were entered into mdoel like Figure below.

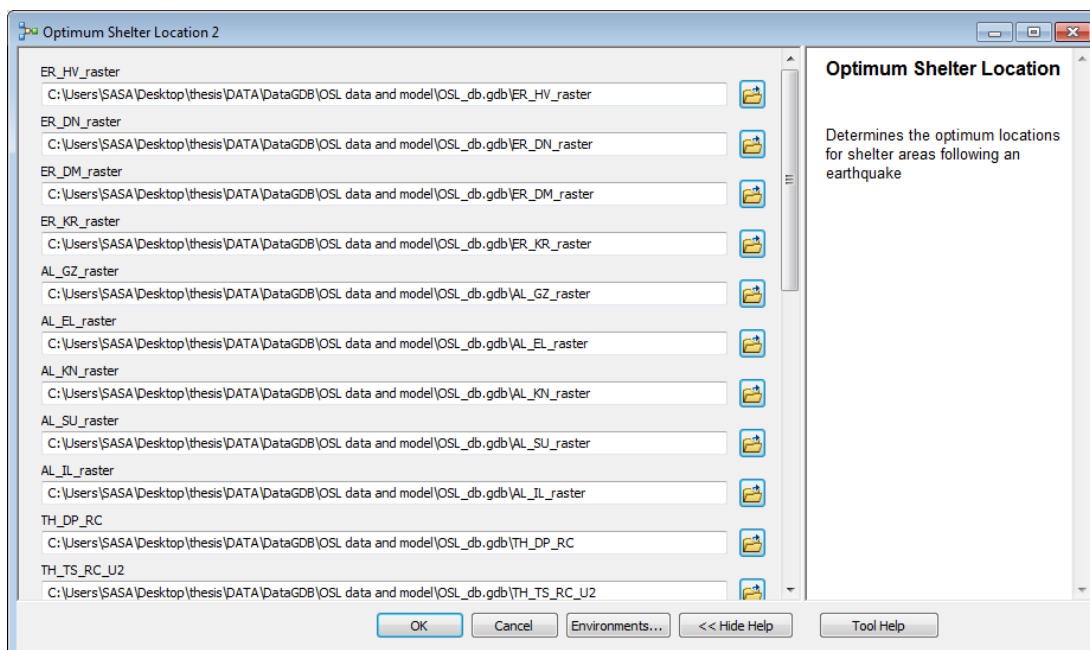


Figure 8.13 : Model Building entering data

The **Figure 8.14** shows the process of each criteria and subcriteria. After applying classification and weighted sum analysis, all the criteria with their weights which were calculated from the questionnaires results. Also capacity and topography maps directly applied to weighted sum (7) because there were already classified and there was no need to do classification and weighted sum analysis on them..After all the other data were classified and applied to weighted sum analysis the last weighted sum (7) applied to the criterias in order to make them ready to classify into 7 classes. After reclassification (10) and running the model the result map showing the optimum locations for shelter site following an earthquake in the city of Istanbul was a Figure like below.

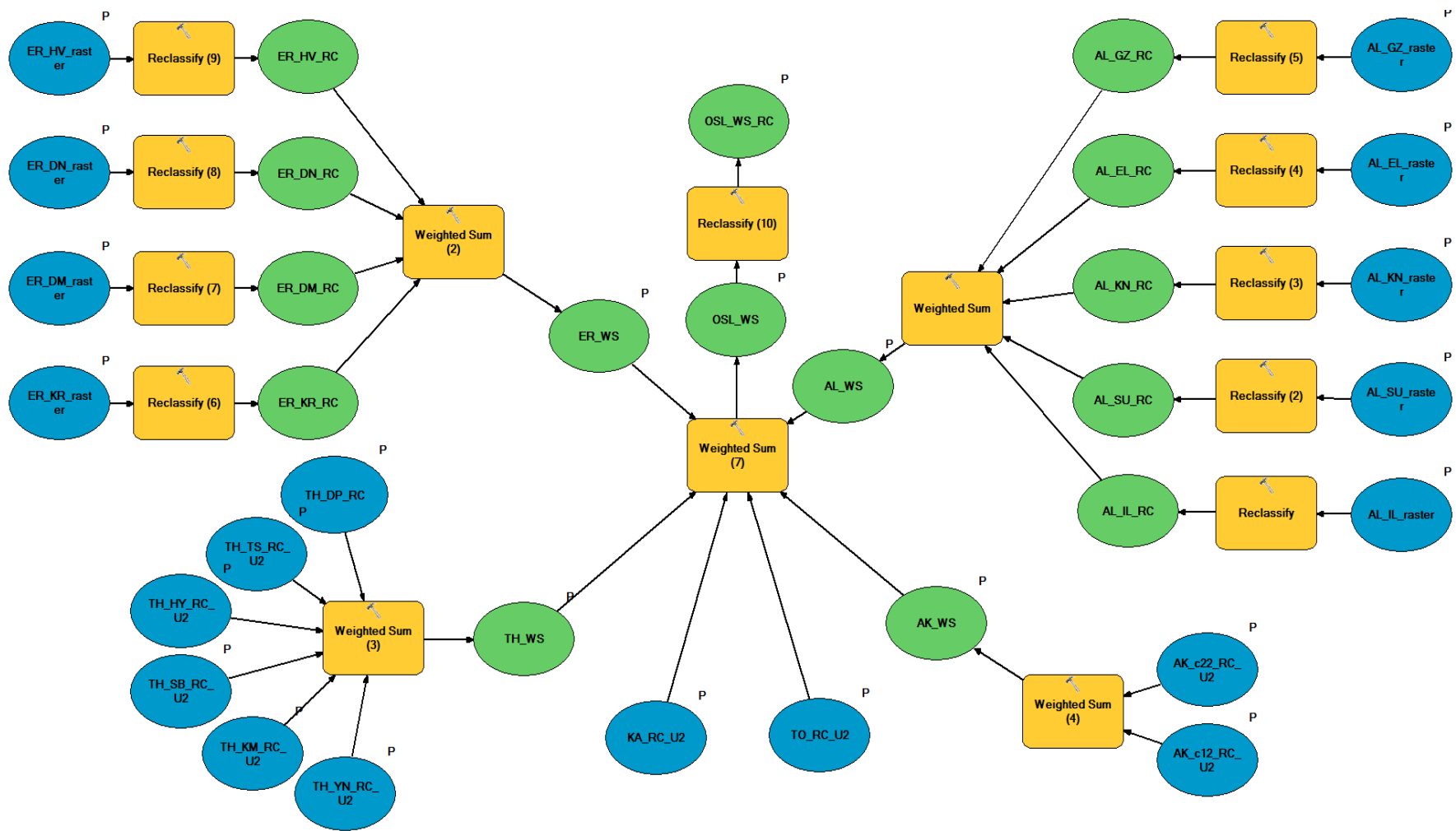
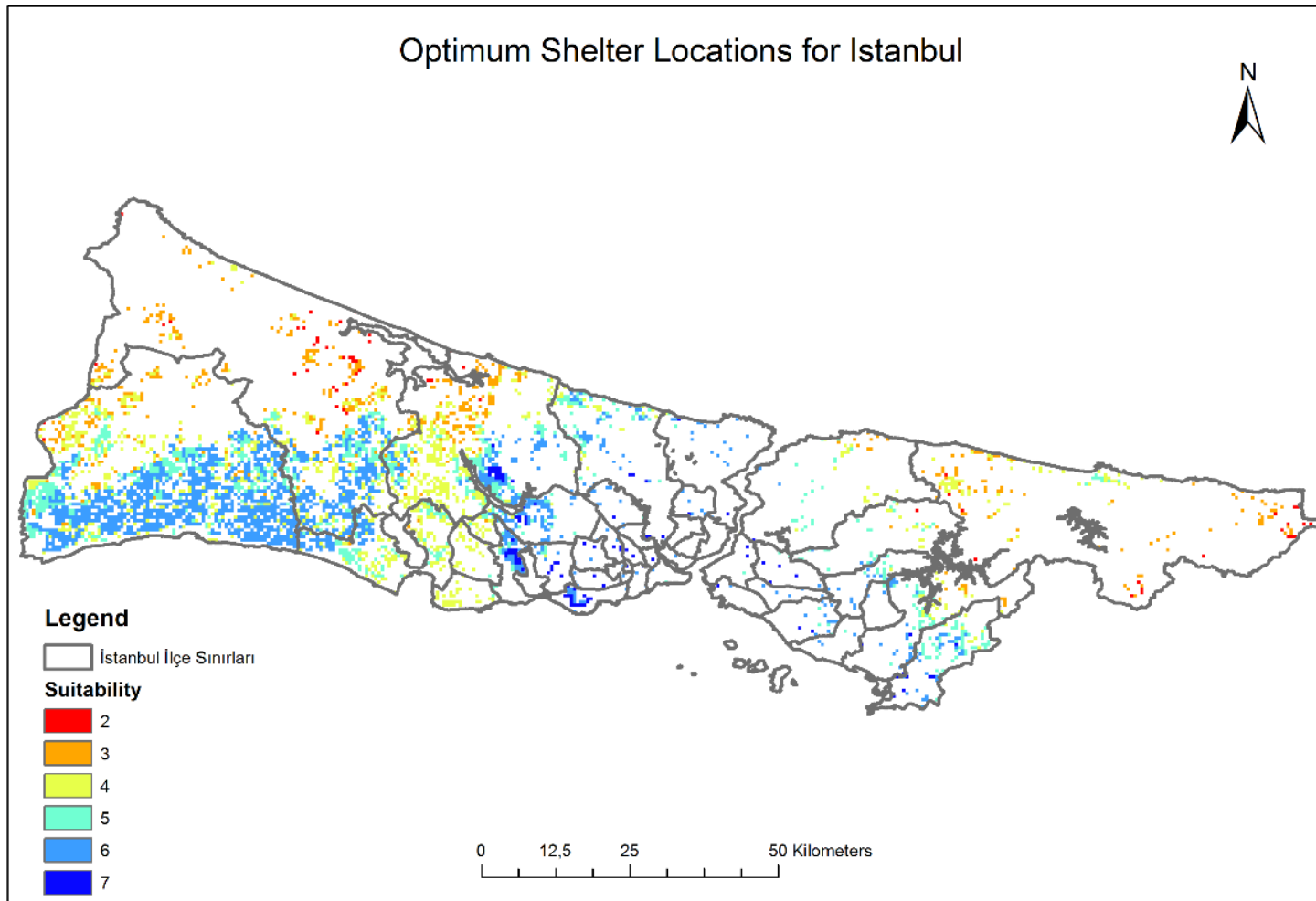


Figure 8.14 : Model of the Study



7 is the most suitable 1 is the least suitable

Figure 8.15 : The resulting map of the model

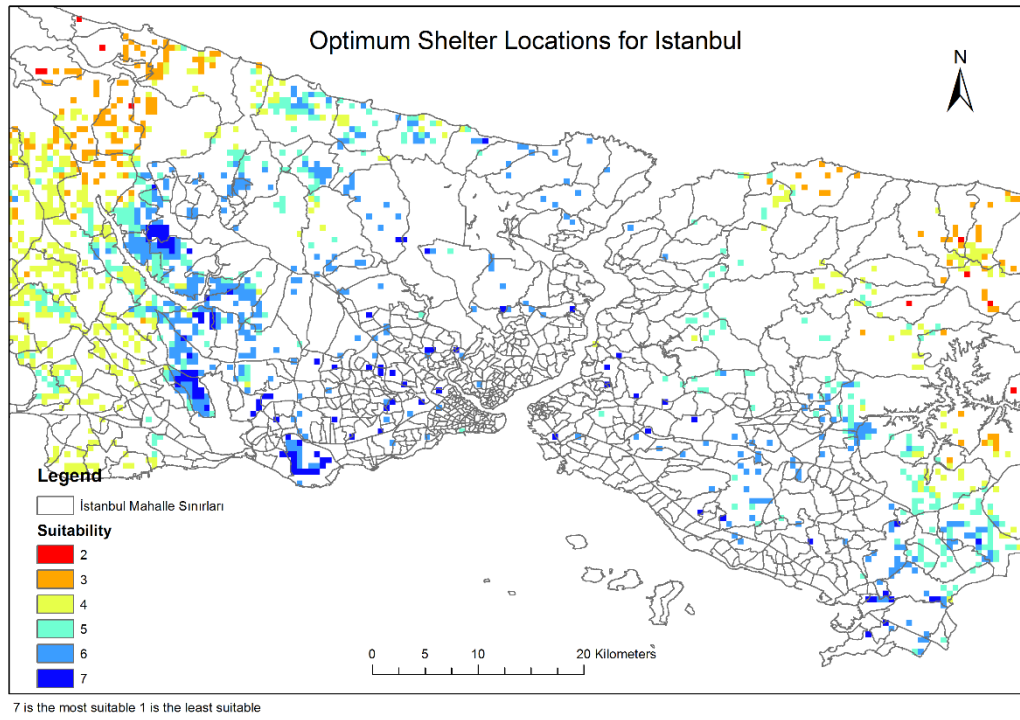


Figure 8.16 : The result map in details

The dark blue areas which have the value of 7 are representing the most suitable areas for establishing a shelter in Istanbul and red areas with the value of 1 are the areas which show the less suitable lands according to the criteria considered in this study.

9. CONCLUSION AND DISCUSSION

The result represented a map, which includes all the criteria and sub-criteria with their importance to offer the suitable areas for temporary shelter location during post disaster phase in a case of earthquake that has a high possibility to occur in the city of Istanbul. The map representation suitable areas which have strong infrastructures, low risk of other feasible disasters, available to access, suitable slope, enough capacity and also the areas which are usable according to their land usages.

As a result of this study some of the safe and suitable areas according to our criteria which have strong infrastructure, being accessible, being far from risk areas, suitable drainage, land usage and capacity.

In European side:

- Arnavutkoy merkez mahallesi
- Arnavutkoy hacimasli koyu
- Basak sehir samlar koyu
- Basaksehir sahin tepe mahallesi
- Avcilar tahtakale mahallesi
- Avcilar firuzkoy mahallesi
- Kucukcekmece istasyon mahallesi
- Kucukcekmece halkali merkez mahallesi
- Bakirkoy yesilkoy mahallesi
- Bakirkoy senlik mahallesi
- Bahcelievler siavuspasa mahallesi
- Bahcelievler kocasinan merkez mahallesi
- Esenler kemer mahallesi
- Esenler havaalani mahallesi
- Sultangazi ugurmumcu mahallesi
- Arnavutkoy mavi gol mahallse
- Eyup defterdar mahallesi
- Eyup yesil pinar mahallesi
- Eyup emniyet tepe mahallsei
- Sisli huzur mahallesi
- Sariyer kisirkaya koyu

- Sariyer resitpasa mahallesi
- Sisli ayazaga mahallesi

In Asian side:

- Tuzla aydinli mahallesi
- Tuzla tepeogren mahallesi
- Tuzla aydin tepe mahallesi
- Pendik Ahmet yesevi mahallesi
- Tuzla yayla mahallesi
- Tuzla istasyon mahallesi
- Pendik sanayi mahallesi
- Pendik kurt dogmus koyu
- Sancak tepe veysel karani mahallesi
- Maltepe buyuk bakkal koy mahallesi
- Maltepe zumurut evler mahallesi
- Sancaktepe pasakoy mahallesi
- Umraniye yukari dudullu mahallesi
- Umarniye kadikoy ataturk mahallesi
- Umariye cakmak mahallesi
- Umraniye kazim karabekir mahallesi
- Uskudar bahcelievler mahallesi
- Beykoz yeni mahalle
- Uskudar guzeltepe mahallesi
- Kadikoy rasinpasa mahallesi
- Kadikoy hasanpasa mahallesi
- Beykoz dereseki koyu
- Beykoz anadolu kavagi mahallesi
- Sancaktepe ferhatpasa mahallesi

If the data are available, this model can be used in any countries and for any type of disaster, with difference that the criteria and standards would change from country to country and disaster to disaster.

Also this method would be useful for decision makers in any type of disaster , man-made or natural, even for modeling the risk areas for criminals or modeling the best place to live in a city.

The first problem about starting this thesis was about installing ArcGIS . normally it is possible from the library but beacause the license was expired and university could not provide it, I had a big problem about installing the program. Since this is a very common use program between Civil engineering and Geomatics engineering students I recommend that it should be available at library.

Second of all the base map in this study was Istanbul-point which includes all the districts in Istanbul with their data, even though the pixel sizes are so small (around 250 m) the result map could not be very accurate. It is better to use each districts map separately to have a more accurate result.

Also I had some problems about the risk maps of Tsunami and Flooding, however my advisor was really helpful about providing the data we could not obtain these data from Istanbul metropolitan municipality directorate of earthquake and ground analysis, until the last two weeks of this study.

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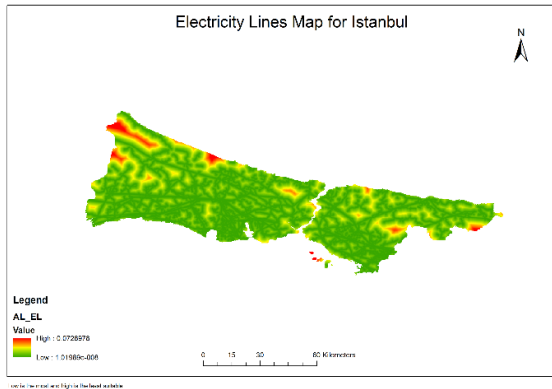
APPENDICES

APPENDIX A: Maps

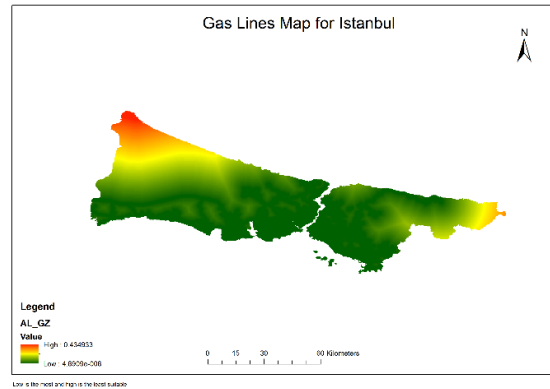
APPENDIX B: Standards for Buildings

APPENDIX C: Standards for Shelters

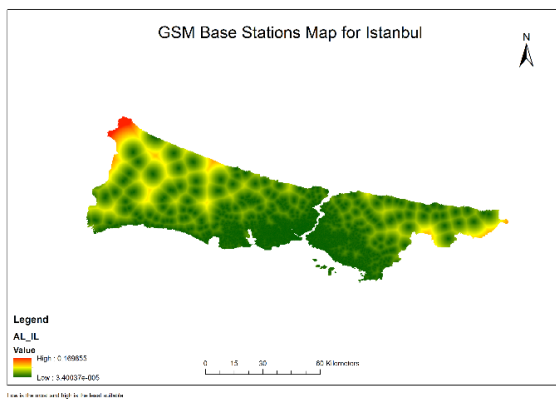
APPENDIX A - INFRASTRUCTURE MAPS



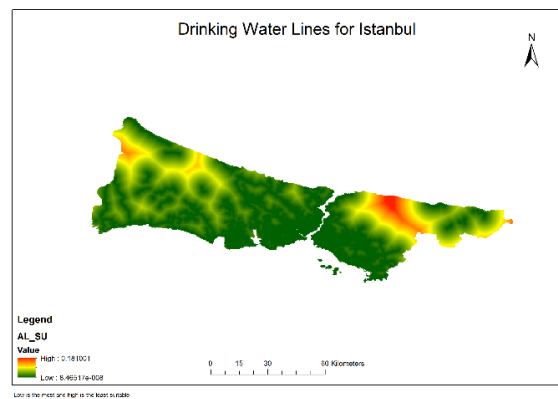
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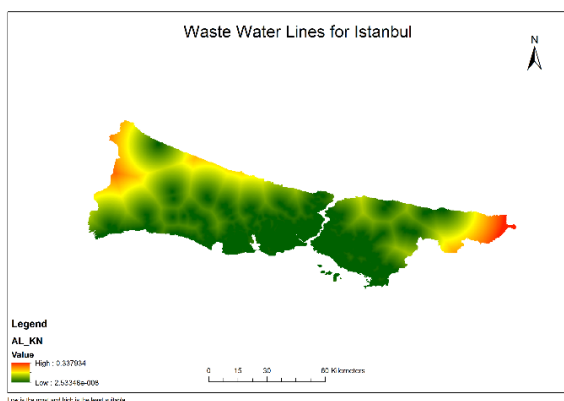
(b)



(c)



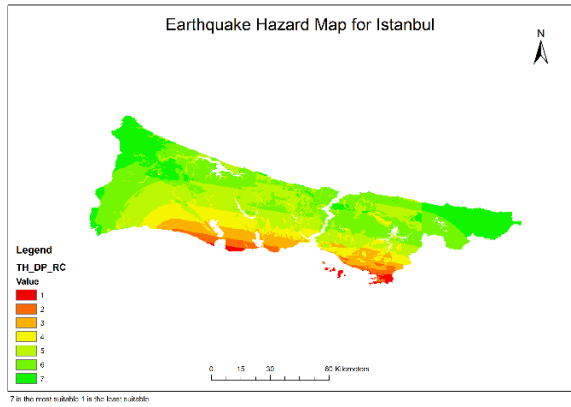
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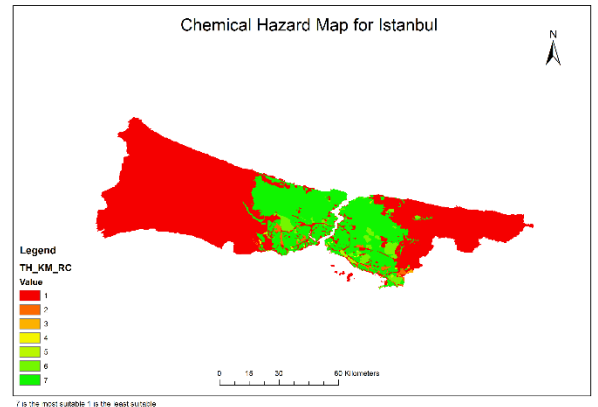
(e)

Infrastructure maps: (a)Electricity. (b)Gas. (c)Telecommunication. (d)Water supply. (e) Sewerage.

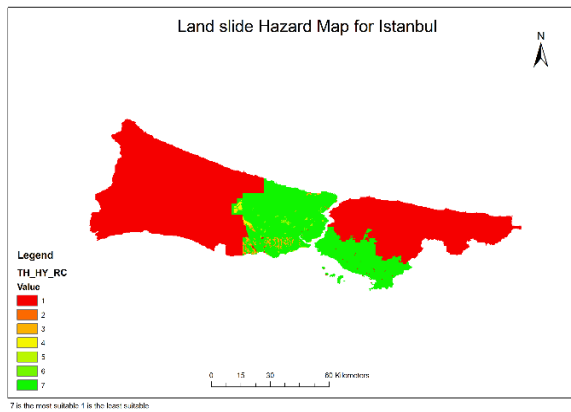
APPENDIX A - HAZARD MAPS



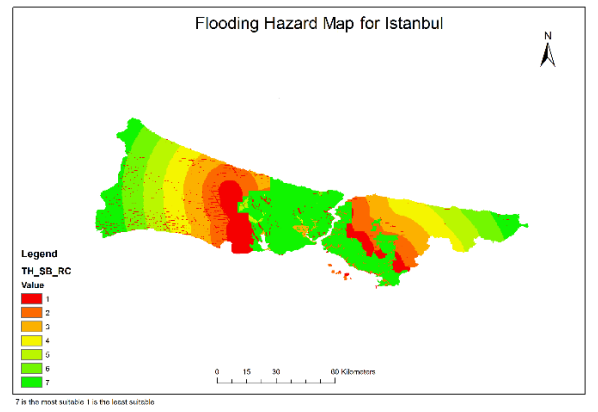
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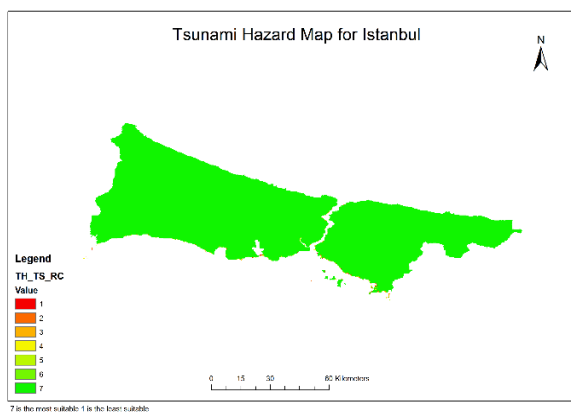
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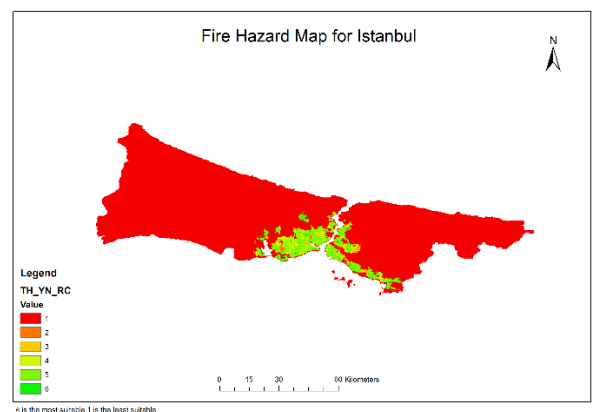
(c)



(d)



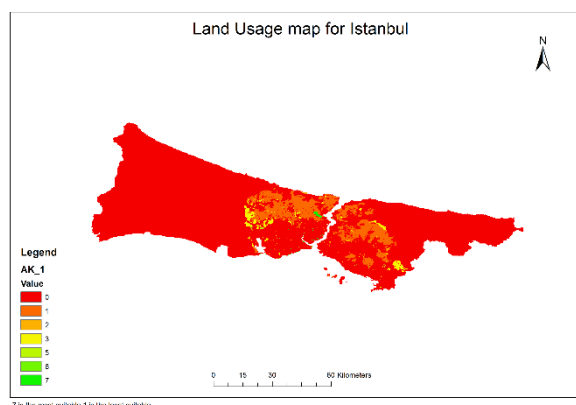
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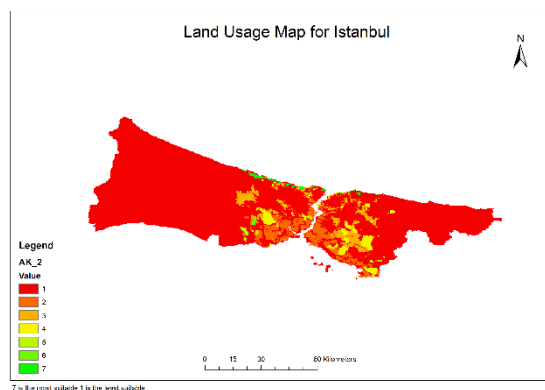
(f)

Hazard maps: (a)Earthquake. (b)Chemical. (c)Landslide. (d)Flooding. (e) Tsunami. (f) Fire

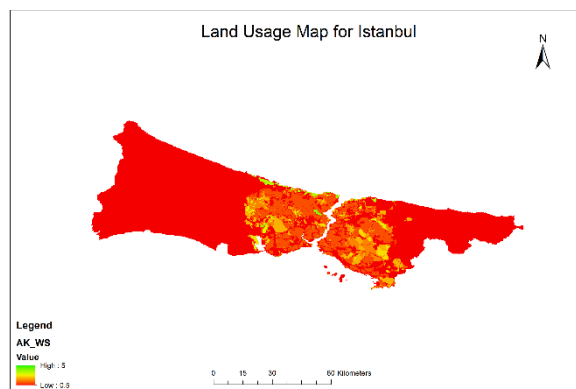
APPENDIX A – LAND USE MAPS



(a)



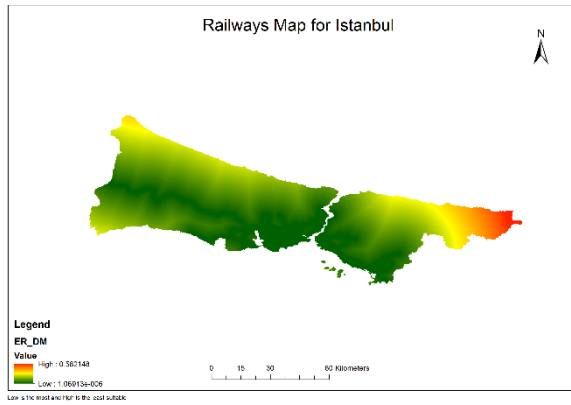
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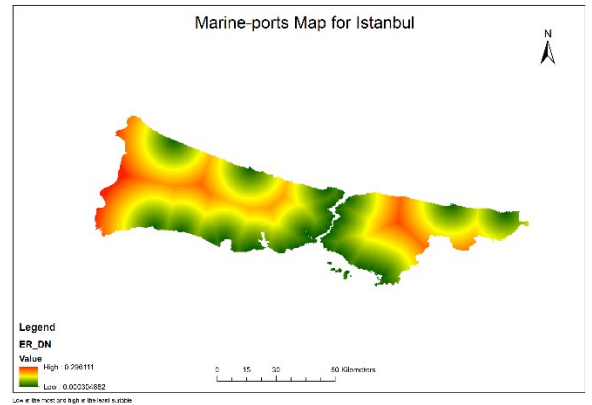
(c)

Land usage maps: (a)Land usage 1. (b)Land usage 2. (c)Land usage

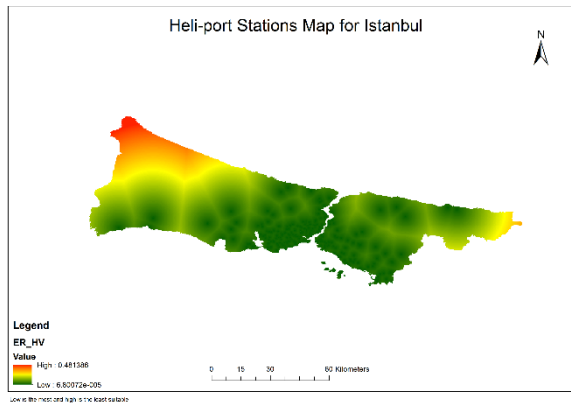
APPENDIX A - ACCESSIBILITY MAPS



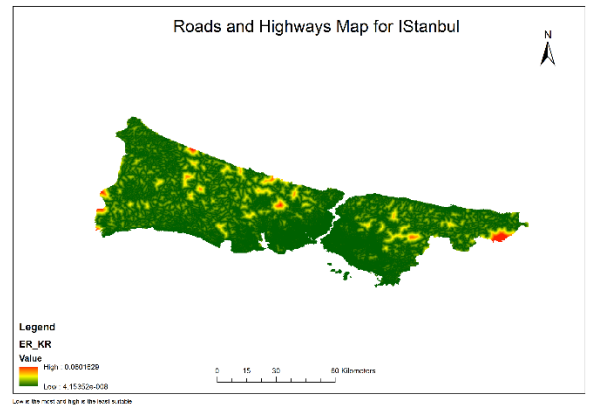
(a)



(b)



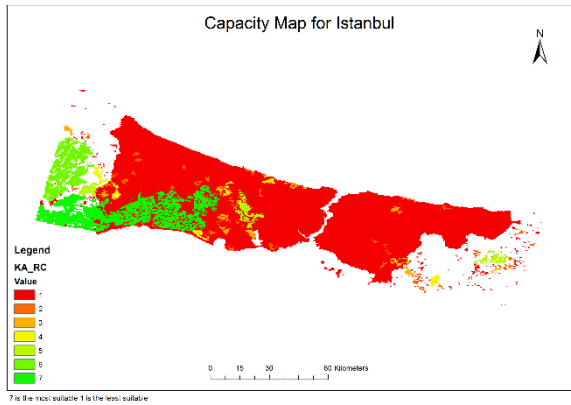
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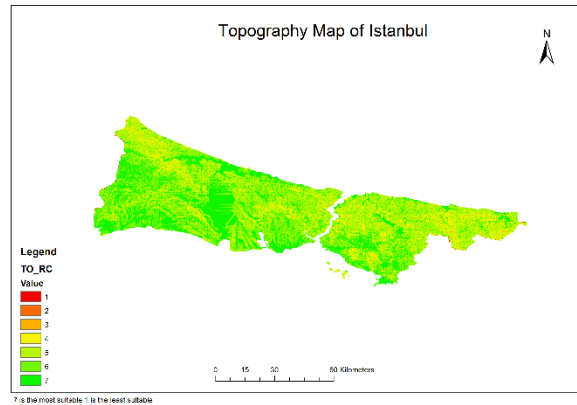
(d)

Accessibility maps: (a)Railways. (b)Marine-ports. (c)Heliports. (d)Roads and Highways.

APPENDIX A – CAPACITY AND TOPOGRAPHY MAPS



(a)



(b)

(a)Capacity. (b)Topography.

APPENDIX B

Standards for buildings

- Whatever the buildings used as temporary accommodation, it is very important that they are only used for a short period, and that they are cleaned and maintained intensively, to avoid a rapid deterioration in environmental health conditions. The following points should be taken into consideration in relation to buildings used for temporary shelter. (Oxfam GB, 2004)
- People sleeping on beds or mats should have a minimum of 3.5m² of floor area or 10m³ of air space. In rooms with high ceilings, double bunk beds may be used. (Oxfam GB, 2004)
- Beds or mats should be separated by a minimum distance of 0.75 metres. (Oxfam GB, 2004)
- Adequate ventilation is required. The amount of fresh air needed is approximately 20–30m³ per person per hour. It may be necessary to provide mechanical ventilation. Whenever possible, smoking and the use of cooking fires in the shelter should be strongly discouraged. (Oxfam GB, 2004)
- An ambient temperature of 15–19 °C is desirable, but lower temperatures can be tolerated with warm clothing. In cold climates, buildings may need extensive repairs and modifications for winter conditions, particularly in conflict situations where windows and insulation material may have been removed or destroyed. (Oxfam GB, 2004)
- To avoid very high temperatures in hot climates, buildings can be modified to increase shade, ventilation and thermal capacity. (Oxfam GB, 2004)
- Buildings should have emergency exits and fire escapes; the flues of stoves used for space heating should extend outside the building; overloading of electrical circuits should be avoided; lanterns and lamps should be placed or suspended so as to avoid dangers; and liquid fuels should be stored outside the building. Clear instructions on fire hazards and safety practices should be displayed in conspicuous places and drawn to the attention of residents; fire-fighting equipment should be available and properly maintained. A group of

volunteers from among the survivors should be taught about the possible fire hazards and trained in the use of fire-fighting equipment. (Oxfam GB, 2004)

- Access to sufficient water for drinking, cooking, and personal and domestic hygiene should be provided. (Oxfam GB, 2004)
- One wash basin should be provided for every 10 people, or 4–5 metres of washbench for every 100 people; there should be separate benches for men and women, and waste receptacles at each bench. One shower head is needed for every 50 people in temperate climates and one for every 30 people in hot climates. Floors must be disinfected daily. (Oxfam GB, 2004)
- Arrangements must be made for human waste disposal. Water-flushed toilets may be available in existing buildings if the water supply has not been interrupted. Outside latrines should be located within 50 metres of the building, but at least 20 metres away from the kitchen, dining hall and water supply. (Oxfam GB, 2004)
- One refuse bin of capacity 50–100 litres should be provided for every 12–15 people. The bins should have tightly fitting lids. Special arrangements for the collection of refuse may be needed if the normal collection service is interrupted. (Oxfam GB, 2004)

APPENDIX C

Standards for shelters

- Whenever possible, the area should be naturally protected from adverse weather conditions. (Oxfam GB, 2004)
- Food distribution areas should be organized so as to create safe conditions for people collecting food, as well as for those distributing it. (Oxfam GB, 2004)
- The surface of roads can be sprinkled with water to keep dust down. Sullage wastewater can sometimes be used to keep down dust on dirt or gravel roads. Restricting traffic and imposing speed limits can also help to reduce dust. (Oxfam GB, 2004).
- Shelters should be arranged in rows or in clusters of 10–12 on both sides of a road at least 10 metres wide to permit easy traffic flow and access by ambulances or firefighting vehicles. In tented areas, there should be at least 2 metres between the edge of the road and the tent pegs. (Oxfam GB, 2004)
- Built-up areas should be divided by 30 metres wide firebreaks approximately every 300 metres. Firebreaks can be used for locating roads and recreation areas. (Oxfam GB, 2004)
- Shelters should be spaced 8 metres apart so that people can pass freely between them without being obstructed by pegs and ropes. This spacing also helps to prevent the spread of fire. If this is not possible owing to a lack of space, the distance between shelters should preferably be at least twice the overall height of each shelter, and should never be less than 2 metres. A separation greater than 8 metres may lead to open defecation and should be avoided. (Oxfam GB, 2004)
- Shelters may be tents or prefabricated units, or may be built out of plastic sheeting together with timber, stone and thatch. Where plastic sheeting is used, it is common to provide one piece, 4 metres by 6–7 metres, per household. (Oxfam GB, 2004)
- Small shelters with few occupants are preferable to large shelters with many occupants. (Oxfam GB, 2004)

- In cold weather, kerosene stoves or other heating appliances should be provided and people should be instructed in their use; every precaution must be taken to prevent fires and explosions. (Oxfam GB, 2004)
- In the absence of electric lighting, wind-proof kerosene or oil lamps, or battery operated lanterns, should be provided for lighting shelters, toilets and roads. (Oxfam GB, 2004)
- Natural ventilation should normally be adequate for temporary shelters such as tents. (Oxfam GB, 2004)
- Refuse bins should be provided. (Oxfam GB, 2004)
- Latrines or other facilities for excreta disposal should be provided (at least one toilet per 20 people), and gradually improved as time and resources allow. The dangers of indiscriminate defecation should be emphasized in health education. (Oxfam GB, 2004)
- Bathing, laundry and disinfection facilities should be provided, and health education should emphasize the importance of frequent hand-washing. One doublesided ablution bench (3 metres long) should be provided for every 50 people. (Oxfam GB, 2004)
- The camp site should be cleaned regularly according to a prearranged schedule. Participation by camp residents in the cleaning of the camp should be encouraged. Young residents can be organized into teams responsible for cleaning and reporting possible health and environment problems. (Oxfam GB, 2004)
- Separate accommodation is necessary for unaccompanied children, with provision for adults (welfare staff and/or community volunteers) to stay with them; there should be at least one adult per shelter or room. These children may be very disoriented and frightened, and may also have special nutritional needs (Adamson and others, 1986). The shelters should be situated near the nutritional rehabilitation centre and field hospital, and as far from sources of secondary hazards, noise and contamination as possible. (Oxfam GB, 2004)
- In conflict and famine-related disasters, many people may be suffering from malnutrition and debilitation when they arrive, so specialized services such as

intensive or therapeutic feeding may be needed. Intensive feeding or nutrition rehabilitation units should be provided with up to 15–30 litres of potable water per bed per day. Also, special care needs to be given to latrines and other waste disposal facilities used by parents, children and staff. Means for hand-washing by all staff and parents concerned with child feeding are also important. (Oxfam GB, 2004)

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