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GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEVELOPMENT OF AN INTEGRATED MULTI AGENT RISK MANAGEMENT PLATFORM FOR FLOOD DISASTER MANAGEMENT

KERİM KOÇ

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DEPARTMENT OF CIVIL ENGINEERING
PROGRAM OF CIVIL ENGINEERING

ADVISER
ASSOC. PROF. DR. ZEYNEP IŞIK

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A thesis submitted by Kerim KOÇ in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** is approved by the committee on 04.12.2018 in Department of Civil Engineering, Civil Engineering Program.

Thesis Adviser

Assoc. Prof. Dr. Zeynep IŞIK

Yıldız Technical University

Approved By the Examining Committee

Assoc. Prof. Dr. Zeynep IŞIK

Yıldız Technical University ______________________

Asst. Prof. Dr. Cenk BUDAYAN

Yıldız Technical University ______________________

Prof. Dr. Gül Polat TATAR

Istanbul Technical University ______________________

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Kerim KOÇ

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LIST OF SYMBOLS

A	Unit utility of action to any specific agent after having time penalty
a_i	Action a taken by agent at the state of e_i
Ac	Set of Actions
Ac_i	Action of agent i
Ag	Set of agents
Ag_t	Characteristics of agents
b_{a_i}	Bad condition weight of action a, related to parameter i
c	Current weight of action
d_{a_i}	Distance between good and bad condition
$De_{Ag,s}$	Deformity that agent Ag put to the system
De_{Ave}	Average deformity of agents
De_{Ag}	Deformity that agent Ag has
e_i	i'th state of environment
$e_{i_{rem,,r}}$	Remaining round of action e taken by agent i
e_r	Round of action e in the game
e_{u_u}	Unit utility of action e in the game
E	Set of environment
$E_{t,eco}$	Economic weight of an action
$E_{t,env}$	Environmental weight of an action
$E_{t,sos}$	Social weight of an action
$E_{t,n,eco}$	Idealized economic weight of an action
$E_{t,n,env}$	Idealized environmental weight of an action
$E_{t,n,sos}$	Idealized social weight of an action
g_{a_i}	Good condition weight of action a, related to parameter i
g-g	Greedy greedy strategy
g-o	Greedy objective strategy
g-s	Greedy social welfare strategy
g-z	Greedy Zeuthen-based strategy
H_{Ag}	Aim of agent Ag
K_a	Total utility of action a
N_{Ag_a}	Idealized value of preference of the agent Ag to action a
p	Probability
p-c	Coward strategy
p-c-o	Coward objective strategy
p-c-z	Coward Zeuthen-based strategy
p-d	Passive direct strategy
p-g-g	Passive greedy greedy strategy

p-g-o	Passive greedy objective strategy
p-g-s	Passive greedy social welfare strategy
p-g-z	Passive greedy Zeuthen-based strategy
p-p	Passive strategy
P_a	Possible penalty of action a
$P_{t,Ag}$	Time penalty of agent ag
q_{i_e}	Capability of agent i over action e
$Risk_i$	Zeuthen-based risk of agent i
R	Set of all possible sequence
R^{AC}	Sequence of all possible actions
R^E	Input from environment
T	Transformer function (Wooldridge, 2002), Set of all possible tasks (Rosenschein and Zlotlun, 1994)
t_a	Round of action a
T_{actual}	Actual project duration
T_{delay}	Delay time of the project
$T_{distance}$	Distance between optimum and worst duration cases
T_i	i'th task
T_{opt}	Optimum project duration
T_{worst}	Worst project duration
$Total_{u_{a_i}}$	Total utility of action a, related to parameter i
$Total_u$	Total utility of each action of each parameter
U_{a_i}	Unit utility of an action a in parameter i
U_a	Total unit utility of an action a
U_{Ag}	Utility of agent Ag
U_{i_a}	Unit utility of action a to agent i
$U_{Net,Ag}$	Net utility that agent Ag takes
U_{Net}	Net utility that is gained by the project
w_i	Relative weight of parameter i
$w_{t_{a_i}}$	Weight of the total utility of action a in parameter i
Z_i	Total utility of agent i up until a specific time
λ	Eigenvalue
Ω	Outcome of actions

LIST OF ABBREVIATIONS

ABM	Agent-based Modelling
AFAD	Disaster and Emergency Management Presidency of Turkey
AHP	Analytical Hierarchy Process
AKOM	Disaster Coordination Center
AKUT	Search and Rescue Team
ANN	Artificial Neural Network
ANP	Analytical Network Process
ASPR	Assistant Secretary for Preparedness and Response
AYDES	Turkish Disaster Management and Decision Support System Research and Development Projects
CI	Consistency index
CP	Compromise Programming
CR	Consistency ratio
BDI	Belief-Desire-Intention
DPEU	Disaster Preparedness Education Unit
DSİ	State Hydraulic Works
ERTSAR	Emergency Response Team Search and Rescue
FEMA	Federal Emergency Management Agency
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographical Information System
IFR	Integrated Flood Management
LTCR	Long-Term Community Recovery
MAS	Multi Agent System
MARA	Multi Agent Resource Allocation
MCDM	Multiple Criteria Decision Making
NGO	Non-governmental organization
PDNA	Post Disaster Need Assessment
PHE	Public Health Emergency
PVC	Poli Vinil Clorur
RI	Randomness index
SAW	Simple Additive Weighted
SBAP	Simulation Based Auction Protocol
TAMBİS	Flooding Response Information System
TOPSIS	The Technique for Order Preference by Similarity to Ideal Solution
TWCM	Total Water Cycle Management
WMO	World Meteorological Organization
UAV	Unmanned Aerial Vehicle

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ABSTRACT

DEVELOPMENT OF AN INTEGRATED MULTI AGENT RISK MANAGEMENT PLATFORM FOR FLOOD DISASTER MANAGEMENT

Kerim KOÇ

Department of Civil Engineering

MSc. Thesis

Adviser: Assoc. Prof. Dr. Zeynep IŞIK

Flood disasters threaten the sustainability of built environment if not managed with an integrated approach. Due to the rapid land use change and uncontrolled urbanization, areas in flood risk zone is increasing tremendously. The flood has impact on people in terms of social and economic welfare, effects public infrastructures, historical places, agricultural areas, flora and fauna. Because of such huge variety of its impact, it is become necessary to achieve integrated solution to work them all together.

The concept of flood risk management is a decision making process including non-structural steps such as land use planning, early warning system developments and emergency response activities. It is not only detection of flood risks and risky areas, but also characterization of mitigation measures and strategies to work on it. In the literature flood mitigation strategies have been studied mainly in terms of strategies between insurance companies, residents and governments. In this study, strategies of flood coordination center and associated institutions were considered to develop an agent-based risk management strategies to mitigate urban flood risks.

First of all, 74 factors were determined with a comprehensive literature review having impact on loss level of flood disaster. Then a pilot study was conducted with 3 experts including faculty members and managers from local authorities to evaluate the reliability of the determined factors and to narrow down all factors into controllable ones. 35 controllable flood factors having impact on flood loss level in the context of built environment were determined under 6 main factors which are; institutional capacity, urban infrastructure, land use, superstructure capacity, demographic and social, and ecologic factors from pilot study. Then a workshop was conducted with 8 experts from faculty members, local authories, institutions for disaster coordination, water and sewerage administration and disaster management were done. Analytical Hierarchy Process (AHP), which is one of the Multi Criteria Decision Making (MCDM) methods, was used to analyze data collected from the experts.

Besides determination of ratings of the factors having impact on flood loss level, 59 flood mitigation measures, associated with each of the controllable factors, were determined from the same expert group evaluating the reliability of the determined flood factors with a brainstorming session.

Since flood mitigation strategies will have the characteristic actions depending on the area where flood occurs, cause and effect relationships were considered in terms of their social, economical and environmental impacts on the area. Then a model in the context of Multi Agent System (MAS) was developped in Python 3 program, to map "course of action plan" in timely manner, as some actions require less time, effort and cost, some others require more. In this model, so as to stick to three dimensions of sustainability, 3 agents were determined as social-based, economic-based and environmental-based as each action has social, economic and environmental aspects of it. These agents were supposed to be sub units of institutions for disaster coordination. Then 13 strategies were determined for agents to so-called "think about", which are mainly the combination of, passive, greedy, social-welfare, objective, zeuthen-based, coward and direct algorithms. MAS requires three main features which are reactivity, proactivity, and social ability. In 3 of the strategies, agents were observed to be reactive and proactive while not socially interactable, in other words they choose actions which will not be a desire of any other agents to negotiate. However, in 10 of the strategies agents fulfill the main features of MAS at all. 8 of the strategies, in some points of determination of actions, if two agents want to have the same action then they try to negotiate, which is one-zero negotiation, meaning that at the end of negotiation one of the two agents takes the action while other searches for new one.

At the end of the process, one of the strategies was concluded to be choosen as it gives maximum utility, however, the best strategy in medium term or short term could differ from that of long term. The model gave action flows including all flood mitigation measures as a "course of action plan" which can be used by institutions for disaster coordination. The study also suggested that social, economic and environmental focus on flood disaster will give more sustainable solutions to mitigate flood risks.

Key words: Multi agent systems (MAS), flood risk management, analytical hierarchy process (AHP), course of action, flood mitigation measures

ÖZET

SEL AFET YÖNETİMİ İÇİN ÇOK ARACILI BÜTÜNLEŞİK BİR RİSK PAYLAŞIM PLATFORMU GELİŞTİRİLMESİ

Kerim KOÇ

İnşaat Mühendisliği Anabilim Dalı

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Sel afetleri bütünleşik bir şekilde yönetilmediği sürece yapılı çevrenin sürdürülebilirliğini tehdit edecektir. Hızlı ve plansız arazi kullanım değişimleri ve kontrolsüz kentleşme sel afet risk bölgelerinin sayısını ciddi derecede artırmaktadır. Sel afeti insanların sosyal ve ekonomik refahına, altyapı ve üstyapılara, tarihi yapılara, tarım alanlarına, bitki örtüsü ve hayvanlara etki etmektedir. Bu etkinin çeşitliliği, sel afetiyle bütünleşik bir platformda baş etme gerekliliğini gözler önüne sermektedir.

Sel risk yönetimi kavramı arazi kullanım planlaması, erken uyarı sistemlerinin geliştirilmesi ve acil durum eylem planları gibi yapısal olmayan önlemleri de içeren bir karar verme sürecidir. Sadece yüksek sel riski taşıyan alanların belirlenmesi değil, aynı zamanda zarar azaltıcı önlemlerin ve stratejilerin belirlenip tanımlanmasıdır. Literatürde sel afeti zarar azaltma stratejileri genellikle sigorta şirketlerine, bölge sakinlerine, yerel ve ulusal yönetim merkezlerine uygulanmaktadır. Bu çalışmada sel afeti koordinasyon merkezi ve ona bağlı alt birimlerin kendi aralarındaki ilişkileri göz önünde bulundurularak stratejik bir karar verme modeli geliştirilmiştir.

Her şeyden önce, sel afetinin zarar düzeyine etki eden 74 faktör kapsamlı literatür taraması sonucu elde edilmiştir. Daha sonra, çalışmanın güvenilirliğini test etmek ve kontrol edilebilir faktörleri saptamak amacıyla akademi ve belediyele yöneticilerinden 3 uzmanla pilot çalışma yapılmıştır. Bu çalışma sonucunda, yapılı çevrede selin zarar düzeyine etki eden; enstitü kapasite, kentsel altyapı, arazi kullanım, üstyapı kapasitesi, demografik ve sosyal, ve ekolojik ana faktörlerinin altında yer alan 35 adet kontrol edilebilir ve yönetilebilir alt faktör belirlenmiştir. Bu faktörlerin ağırlığını belirlemek için üniversitelerden, yerel belediyelerden, afet koordinasyon ve yönetim

enstitülerinden, su ve kanalizasyon idarelerinden sel afet yönetimi ile ilgili çalışmaları bulunan 8 uzman ile bir çalıştay düzenlenmiştir. Uzmanlardan toplanan verilerin analiz edilmesi için çok kriterli karar verme yöntemlerinden biri olan Analitik Hiyerarşi Süreci (AHS) kullanılmıştır.

Sel afetinin zarar düzeyine etki eden yönetilebilir faktörlerin ağırlıklarının belirlenmesinin yanısıra, bu faktörlerle ilişkili 59 tane sel zarar azaltma önlemi yine aynı uzman ekip tarafından beyin fırtınası yöntemi ile belirlenmiştir.

Sel zarar azaltma stratejilerinin, selin meydana geldiği bölgeye bağlı olarak, kapsadığı bazı karakteristik eylemlerine karşı, eylemlerin sosyal, ekonomik ve çevresel etkileri ışığında neden sonuç ilişkileri göz önünde bulundurulmuştur. Daha sonra gerekli eylem planını saptayabilmek için, Python 3 programı kullanılarak bir Çok Aracılı Sistem (ÇAS) modeli geliştirilmiştir. Model, eylemlerin değişen zaman, efor ve maliyetini göz önünde bulundurmak amacıyla zamana bağlı bir şekilde geliştirilmiştir. Bu modelde, sürdürülebilirliğin 3 boyutu olan sosyal, ekonomik ve çevreselliğe bağlı kalmak amacıyla, sosyal tabanlı, ekonomik tabanlı ve çevresel tabanlı 3 ajan oluşturulmuştur. Bu ajanlar afet koordinasyon merkezlerinin alt enstitüleri olarak düşünülebilir. Bu ajanların kendi aralarında pazarlık yapması ve işbirliği içinde olmaları için 13 adet strateji belirlenmiştir. Bu stratejiler genel olarak pasif, aç gözlü, sosyal faydacı, hedefe yönelik, Zeuthen risk tabanlı, korkak ve direkt (passive, greedy, social welfare, objective, Zeuthen-based, coward and direct) algoritmaları ve bunların birleşimlerinden oluşturulmuştur. ÇAS içerisindeki ajanların 3 ana özelliği reaktif, proaktif ve sosyal beceridir. 3 stratejide ajanlar sosyallik dışındaki iki ana özelliği sağlamıştır. Yani seçtikleri eylemler, o eylemler bitene kadar diğer başka bir ajana çekici gelmemiştir. Diğer 10 stratejide ise ajanlar ÇAS'in 3 ana özelliğini de sağlamıştır. Bunlardan 8 tanesinde sürecin en az bir noktasında ajanlardan biri, diğerinin gerçekleştiriyor olduğu eylemi almak için pazarlık yapmıştır. Bu pazarlıkta ajanlardan biri eylemi alır ve gerçekleştirir, diğeri ise yeni bir eylem arayışı içine girer.

Süreç sonucunda, stratejilerden bir tanesi en fazla faydayı sağladığı için baskın strateji olarak seçilir, fakat baskın strateji uzun dönem, orta dönem ya da kısa dönem için farklılık gösterebilmektedir. Modelin çıktısı sel zarar azaltma önlemlerinin akış listesidir. Bu çıktı, "eylem planı çatkısı" olarak düşünülüp afet koordinasyon merkezleri tarafından da kullanılabilir. Çalışma ayrıca, sel afetinin etkilerinin sosyal, ekonomik ve çevresel olarak ele alınmasını ve bunun sürdürülebilir bir yapılı çevre için öncü olacağını öne sürmektedir.

Anahtar Kelimeler: Çok aracılı sistemler (ÇAS), sel afet yönetimi, analitik hiyerarşi süreci (AHS), eylem planı, sel zarar azaltma önlemleri

CHAPTER 1

INTRODUCTION

Disaster is defined as unexpected events resulting in destructive consequences. All over the world, disasters cost billions of dollars and it is agreed that disaster mitigation measures could compensate for its efforts. Disasters are caused by mainly integration of two phases: disastrous event and inability to cope with it. While inner indicates the hazardous part, latter indicates vulnerability. In terms of flood disaster, it has been increasing all over the world over the last decades. Besides, mitigating variety of risk of flood is complex but controllable process.

1.1 Literature Review

Flood disaster has huge impact on infrastructures, economic activities, social system and ecosystem [1]. In the context of flood disaster management, there are hundreds of factors having impact on its destructiveness, from hydrologic to land use, from economic to social, which addresses the necessity of integrated solution. In the literature, there are several studies done similar to this issue; however, most of them are related to specific area, structure or perspective. For instance Dang et al. (2011) worked on parameters impacting flood risk in Day River Flood Diversion Area, Red River Delta, Vietnam [2], Kelman and Spence (2004) worked on flood actions on building [3], Jonkman and Kelman (2005) studied on causes of flood disaster deaths [4], Mirza (2001) examined global warming and flood probabilities in Bangladesh [5], Ruin et al. (2008) worked on human exposure to flash flood in Southern France in 2002 [6]. Only Alpay and Green (2006) give some insights into typical activity list of disaster operations in mitigation, preparedness, response and recovery phases, which is for disaster general rather than flood disaster [7]. In terms of global outlook, all factors and all actions related to flood were not found in the literature. In order to mitigate flood risks, general mechanism or system should be achieved, which could help disaster coordination centers to behave more effective by adopting such system.

In the context of integrated flood risk management approach, it is characterized by Hall et al. (2003) as; comprehensive definition of the structure of flood, continuous management of flooding, deeper analysis with decision making support systems, consideration of the broadest possible set of flood management actions, development of integrated strategies which combine flood actions and working them in programmed way, recognizing and improving the current legal frameworks [1]. This characterization in most of the way suits to our study. Besides, Hooijer et al. (2004) addresses that in order to decrease damage of flood events for different flood types there is a need of determination of different strategies. Therefore objectives and flood mitigation measures should be diversified for different type of floods for specific areas [8]. Böhm et al. (2004) also suggest that objectives should be clearly defined for different regions to mitigate flood risks [9]. Moreover it is mentioned at [1] that, integrated approach can be achievable with analysis of the whole system, evaluation of consequences of strategic interventions and coordination in strategic interventions.

In Multi Agent Systems (MAS), which consist of multiple agents capable of making decisions autonomously, flooding were used mostly in terms of negotiations between insurance agencies, government and residents [10], integration of hydrodynamic simulation and agent simulation [11] or agent based flood evacuation simulations [12]. There is also a gap in the literature in determination of "course of action plan" in terms of flood disaster mitigation measures in the context of strategic interventions of multiple agents.

1.2 Objective of the Thesis

The research is mainly focused on the determination of flood mitigation measures as a "course of action plan" and to allocate these measures to social, economic and environmental agents so as to develop flood disaster risk management model in the context of sustainability of the built environment. In the phase of modeling, Multi agent system methodology was used for agents to negociate and to collaborate in terms of differing strategies.

As flood disaster risk management literature was focused more on conceptual frameworks or engineering aspects of it rather than practical solutions in the context of decision making process, proposed model has considerable contributions to literature as well as institutions working on flood disaster mitigation. The use of predetermined strategies in the context of MAS, it is become more realistic to work on flood disaster as these strategies are similar to real life interactions. This study aims to develop a multi agent model to allocate flood mitigation measures in terms of social, economic and environmental aspects of it as well as to help institutions for disaster coordination to work on specific measures in the sequence of importance. This study also recommends such institutions to adopt social, economic and environmental departments to achieve sustainable flood disaster management.

In this respect, the followings are the objectives of this thesis:

- Determination of all risk factors affecting flood loss level with frequency analysis.
- Determination of the controllable risk factors affecting flood loss level and their relative weights.
- Determination of the flood mitigation measures and their relative weights which will be used in the agent environment.
- Determination of different strategies for agents to negociate.
- Development of agent-based system to distribute flood mitigation measures to agents in social, economic and environmental terms and to analyze results.

1.3 Hypothesis

Flood factors and developed agent-based model with the strategies of agents, there are a number of 6 hypotheses in the framework, which are listed below.

H_1: Factors affecting built environment in terms of social, economic and environmental aspects could help to create reasonable flood disaster risk management system.

H_2: Determination of the flood disaster mitigation measures affect decision making processes positively by adopting agent-based modeling.

H_3: Flood mitigation measure interventions can increase the utility of the system by agents' relationship with each other.

H_4: Dual intervention strategy of activities could give more sustainable results than passive strategies by considering time penalty in terms of flood disaster management.

H_5: Greedy strategy of an agent gives more utility than that of coward strategy for flood disaster management.

H_6: The objective of an agent can alter the negotiation processes and it will give more sustainable solutions for flood disaster management.

CHAPTER 2

DISASTER MANAGEMENT – GENERAL VIEW

In this part of thesis, definitions related to disaster classification and considering different types of disasters, answering the basic questions about disasters from literature that comes into mind when disaster is first thought and flood disaster will be presented. Literature related to disaster management concepts and flood disaster management will also be the focusing area of the following chapter.

2.1 Etymology and the Meaning of the Word 'Disaster'

The word disaster was first encountered in 1590s which is derived from disastro (dis + astro) from Italian and in these times astro were used as 'star, planet' in Latin literature. The sense of disaster is actually astrological with the meaning of a holocaust blamed on an unwanted position of a planet [13].

When state-of-the-art outlook on definitions are concerned, several different types of definitions for disaster were encountered. For instance, it is defined in Cambridge Dictionary as an incident leading to harm, damage or different sorts of difficulties [14].

By focusing on physical stress, it has been defined by Quarantelli (1985) as physical impacts of physical agents, social depression or crisis situation resulting from such physical stress [15]. Unless the capabilities of anything are perfect, there is a probability of disaster whose damage could be reduced with appropriate precautions.

Disaster was also seen as an incident which is below the power of the first replicants to control or overcome, resulting in critical damages and more service destruction at some distinct areas, moreover a number of casualties [16].

Another definition for disaster was mentioned as an incident which is caused by seismologic, meteorological or epidemiologic combinations of triggers resulting in negative physical and socioeconomic consequences [17].

It was also described as a “serious disruption of the functioning of a society, causing widespread human, material or environmental losses which exceed the ability of a society to cope using only its own resources” [18].

From the light of above, it can be said that there are a huge number of definitions of disaster but the meaning of it should include at least one of the following descriptions;

- It is an event resulting in great harm or difficulty,
- It is an incident occurs unexpectedly,
- It is a crisis situation exceeding the capabilities,
- It occurs when respond have no power to overcome,
- Its impact could be reduced by appropriate precautions.

2.2 Classification of Disasters

Disasters are broadly divided into natural or man-made disasters, although complex disasters could occur mainly in developing countries, where there is no single cause. In addition, in some occasions, disasters may spawn other secondary disasters that could enhance the hazardous effects of incident. Earthquakes could be given as a good example for it, with the possibility of a tsunami leading to coastal flooding. Disasters related to man-made or natural ones are shown at Figure 2.1 with causal and occurrence style. As it can be seen, there must be a problem related to capability of response, which is the feeding point, in order for event to be regarded as a disaster.

As another important point that should be considered from Figure 2.1, after disasters divided into natural or man-made, there is another separation for both of the disaster styles into sudden occurrence and progressive occurrence. Even though disasters are generally considered as events that take place suddenly with causing serious damage in short time periods, some disasters occurs very slowly but people suddenly realize that they are in a disaster and may continue for more period of time. Total damage might not be known for a long time and people may not be aware of effects and the cumulative damage of it until it reaches crisis [19]. It can be said that, ‘sudden’ as a concept, could be related to disasters by means of whether occurrence of it or awareness of it.

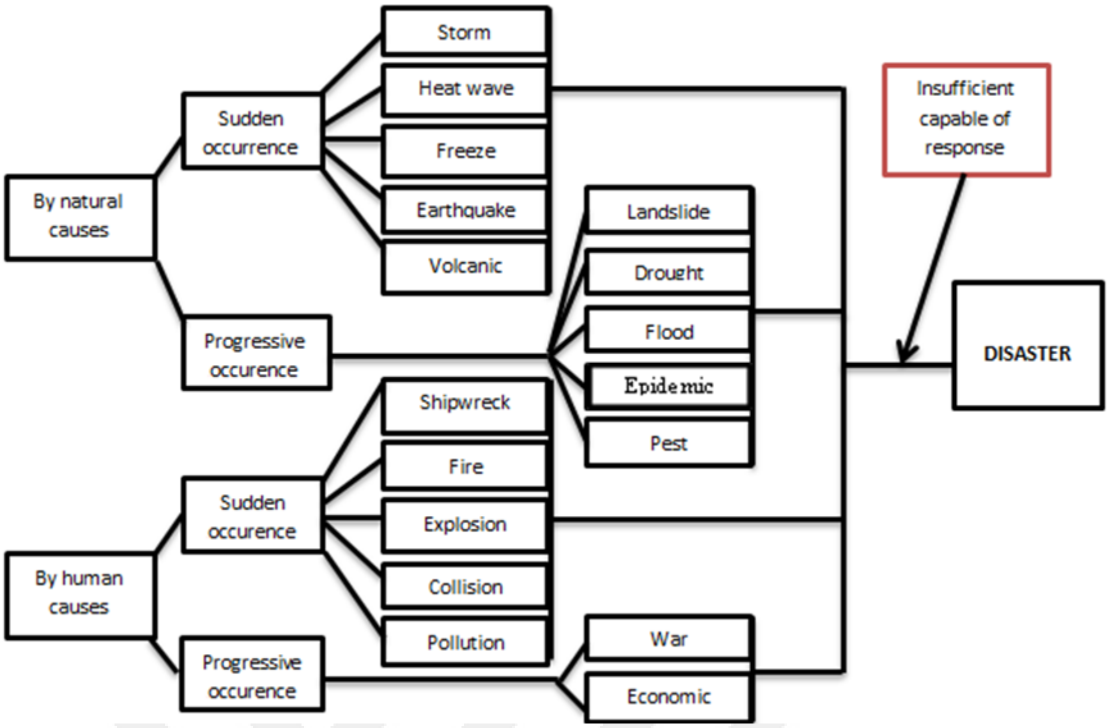

Figure 2.1 Disaster classification [20]

2.3 Basic Concepts Related to Disaster

In order to examine and develop a concept of disaster, or trying to overcome some difficulties with regard to disaster, it is necessary to define it. In order to have appropriate knowledge about disasters, there are a huge number of basic questions, however, only the questions related to occurance, beginning and prevention of disaster will be mentioned.

To work on disasters, there is a need to look at the root of the creeper “disaster”. ‘Why disaster occurs?’ is a basic question related to this inquiry, helping us to work disaster out. It can be said that disaster consists of two main phenomenons which are hazardous event and inability to manage with it, in other words vulnerability [21]. It can also be said that disaster is a hazardous event that may cause negative concequences and occurs when the society have no ability to manage its consequences or it cannot overcome the difficulties related to the causes. Single hazard or vulnerability does not lead directly to disasters. Instead, single hazard could be regarded as an indicator of a disaster while vulnerability can be regarded as a potential of disasters. Earthquakes, floods, volcanic eruption and other disastrous events can be regarded as the indicator part of disaster. Besides, some of the reasons for vulnerability can be seen at Table 2.1.

Table 2.1 Vulnerabilities possibly resulting in disasters [20]

Underlying Cause	**Dynamic Pressures**	**Unsafe Conditions**
Poverty	Lack of;	Fragile Environment
Limited access to power Structures and resources	Education, Training, Local market, services, press freedom, institutions	Dangerous Locations Dangerous Buildings Dangerous environment
Age, Ideologies	Macro-Forces;	Low level of income
Economical System	Urbanization	Livelihood at risk
Disabilities and illness	Environmental degradation	Public Actions

It can be said that disaster can easily emerge with the combination of hazardous event and vulnerability. This can be resembled with antigen-antibody relationship. When disaster is concerned, it can be said that Antigen = Hazardous event, Antibody = Respond to event. If antibody does not have enough power to spirit away the antigens, it means there is vulnerability. It can be said that co-occurrence of hazardous event and vulnerability could result in, while in terms of human body, sickness; in terms of humanity, disasters.

The question “when does a disaster begin?” is also a basic but meaningful question to grasp the concept of disaster. It is crucial that there are two main factors that could trigger the disaster potential, which are human population and potentially destructive agents [22]. However, disaster actually begins before the presence of any precise agent. Agents, leading to disasters could occur prior to any sign of disaster, because of either human-made or natural effects of it.

The answer is most of time unclear. Butterfly effect can be thought as a good example for it, which is one of the well-known chaos theories. In this theory, it was mentioned that small causes may have momentous effects [23]. Such effects are similar for disastrous events because disaster occurs and leads most of time a chaotic process in the nature. The question can be answered as, the time of the first agents of the most of the disasters are remain unknown because of the complexity of the structure of disasters. However, it can be said that events can be regarded as a disaster when the consequences are become more distinct.

By thinking of the prevention of disasters, it can be said that, most hazardous events leading to disasters cannot be prevented purely; however, their impacts can be reduced. As it was mentioned, the society's effect on consequences of a disaster is crucial because we human beings are forming the vulnerability part of disasters where hazardous events are natural. From this perspective, beforehand in terms of preparedness or afterwards in terms of response and reconstruction, could decrease the destructive impacts of it.

2.4 Concepts and Types of Disaster Management

Disaster management can be defined as a planning and acting process so as for people to be prepared before disaster, to relief during disaster and to reconstruct after disaster [24]. The concept of disaster management includes different sections such as, reducing risks for disaster to occur, relieving and helping people to survive during disaster and to overcome difficulties afterwards.

2.4.1 Importance and Benefits of Disaster Management

As disasters can be viewed as a process of risk, there is, inevitably, need to reduce these risks and negative consequences of it. Because of the impacts of disasters on social life, economy, physical infrastructural and the environmental losses, it is becoming increasingly crucial to manage disasters in terms of beforehand, during and afterwards.

Recently, there has been a sharp increase in natural disasters. For instance, while between 1900 and 1909 the occurrences of natural disasters were 73 times, it was 2788 between 2000 and 2005 [25]. It is obvious that technological developments have been increasing meantime, which make it more viable to embed such developments into disaster mitigation strategies.

As a result of disaster management strategies, the capacity of institutions working to mitigate its impacts increases leading to save more lives, to have more sustainable infrastructures, to decrease in economic losses and to create sustainable societies, from the beginning to the end of its interventions.

As another perspective over disaster management, there is an interruption of disasters to societies by decreasing the quality of lives, creating victims and problems in infrastructures, houses and any kind of properties. Budget that is intended to be used for the purpose of development, inevitably, diverted to respond to these disasters. Society, economy and environment are three major components of sustainability. Because of disasters, lack of respond and control over them, there are significant threats to the sustainability of regions that disaster occurs [26].

It can be said that in order to achieve sustainable developments by having control over disasters as they occur or are realized suddenly, there is an absolute need to have disaster management plan. It is obvious that the cost of disaster management plan could cover the cost of respond in comparison with having no plan, by saving lives, sustaining houses and infrastructures, maintaining sustainable developments.

2.4.2 Types of Disaster Management

As it has already been mentioned, there are mainly two types of disasters, which are natural and human-made. In terms of natural disaster, there are different kinds of consideration types on disaster management. One of the most used disaster management classifications is the one depending on event types. It includes storm, flooding, earthquake, drought, epidemic, volcanic eruption and so on [27]. The number of disaster occurrences in each year, from 1994 to 2014, is shown by types of disasters at Figure 2.2. Occurrences of disasters vary from nearly 270 in 1994 to 520 in 2000 [27]. As it can be seen, flood disaster is the most occurred disaster type between 1994 and 2014 and the occurrence percentages of flooding varies from nearly %25 in 1998 to %46 in 2006.

There is another classification of disaster management focusing mostly on time. To manage an event it is necessary to consider before, during and after the event separately [28]. Then these separated management approaches can be gathered to have integrated approach.

It is obvious that before a disaster there is a preparedness stage which is taken into account to reduce human and human-related losses. By considering that, there is a significant need of response to disaster in order to manage difficulties during disastrous events. Under this phase, the main focus is to minimize destructive consequences with the concept of emergency response. As a final stage, post-disaster management activities are taken, the phase is known as a recovery stage.

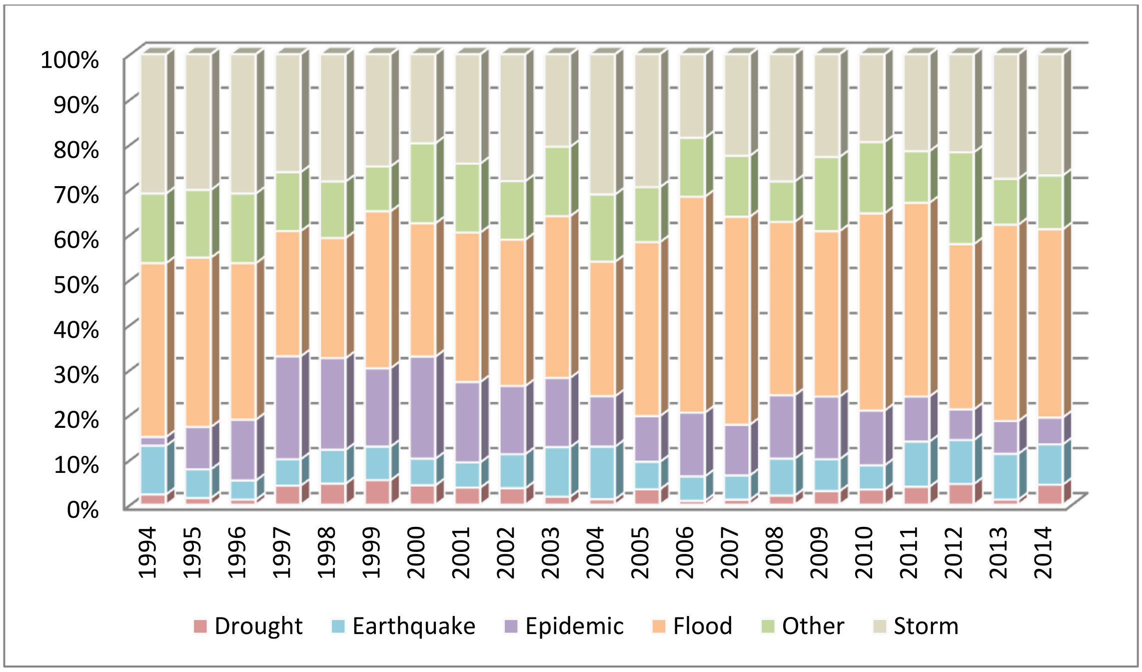

Figure 2.2 Percentages of recorded natural disasters, worldwide, by type – 1994 to 2014 [27]

Recovery stage includes activities related to early recovery, rehabilitation to community and reconstruction. General scheme of disaster management, separated to actions by considering the time concept is shown at Figure 2.3.

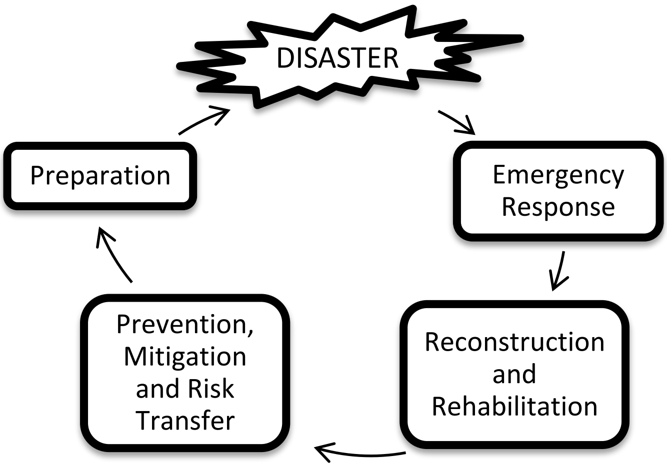

Figure 2.3 Disaster risk management [28]

Before, during and after disaster management outlooks will be examined more deeply with theoretical and practical activities.

2.4.2.1 Pre-Disaster Management: Preparedness and Mitigation

Main aim of disaster preparedness is preparing community to disasters; hence they can response to disaster most effectively when it occurs.

When the whole concept 'preparedness' is concerned, it is hard to evaluate difficulties and possible risks. It can be said that in order to construct sustainable preparedness process, it is necessary to disaggregate preparedness into its elements [29]. The elements of preparedness stage can be summarized as planning, training, organizing equips, exercising and evaluating [30].

In order to make such precautions, there is a need of providing information to individual about how to mitigate their consequences and this will encourage public preparation [31]. However, it is not always easy for people to take such precautions.

It was addressed that there are some variables that trigger people to have intention over preparedness as the social-cognitive preparedness model as Figure 2.4 illustrates.

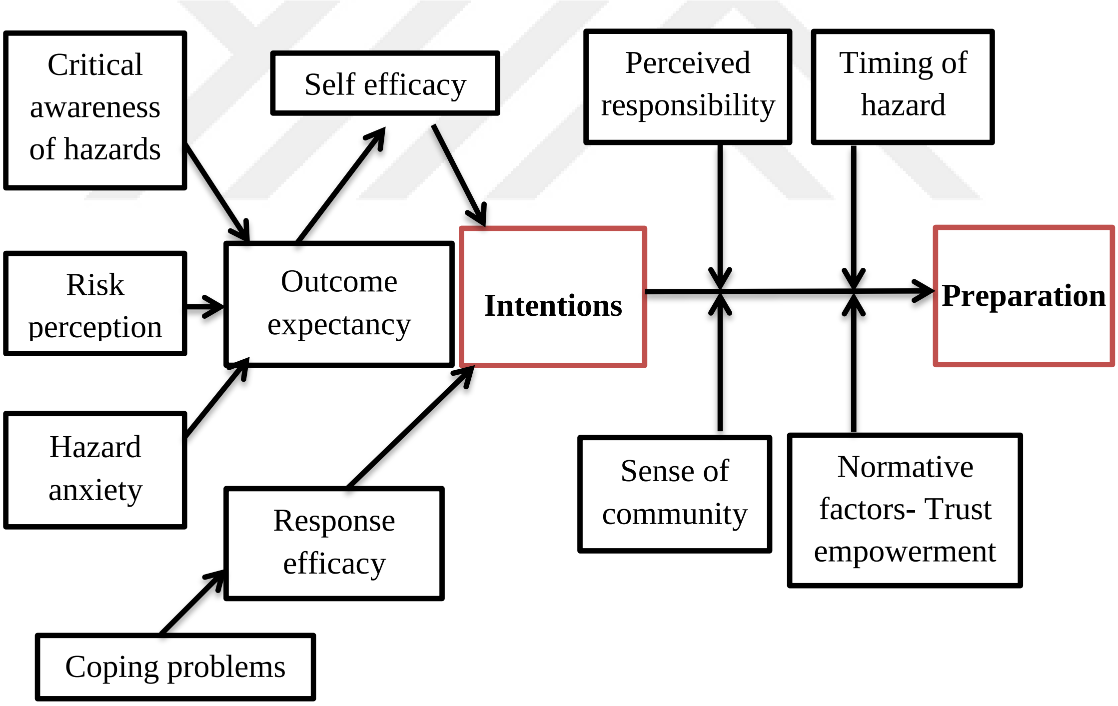

Figure 2.4 Social-cognitive preparation model [32]

It can be said that, anxiety and fear is the core variables that trigger people to intention [32]. Outcome expectancy is a necessity as it can give a reason for people to act, in other words people need to see disaster as a surmountable event. Besides, from public perspective they should see themselves competent to act which is shown as efficacy. After having intention there are some feeding points in order for intention to continue which are perceived responsibility, sense of community, normative factors and timing of hazard activity as shown on the right part of the Figure 2.4.

Besides social-cognitive preparation, from another perspective, preparedness can be divided into household, organizational, inter-organizational and community preparedness [33]. While household preparedness comprises awareness of hazard, self-education and having emergency plan at home, organizational preparedness addresses rational emergency management with more pluralistic view on issue. Finally, inter-organizational and community preparedness focus mainly on inter relationships between organizations, people and institutions. However, there are some obstacles to have sustainable interrelated approach, one of which is structural differences. To have this approach there is a need to convert any organization into the same foundation structure [33]. Cooperation between such organizations is vital. When there is no disaster, such groups can behave independently. However, with the occurrence of disaster, probably none of them have enough power to overcome negative consequences by one, which make it crucial to establish communication and cooperation between organizations as an emergency plan [34].

There is another type of plan that can be regarded as one of the pre-disaster phases focusing on the importance of policy development and law enforcement. It is obvious that sometimes it takes some time to decide and enforce when unwanted event occurs. Because of the magnitude of the time during disaster there is a vital need to have some policy plans that enables institutions and authorities to react as fast as possible in order to reduce the negative impacts of disaster [35].

Seaber et al. (2017) addressed that pre disaster management phase consists of 2 main class which are mitigation and preparedness. At that study [36], the literature of game theory applications of disaster management was examined, showing that investing in defense against disaster is one way to mitigate destructive events. In that study it is addressed that some of the remaining interest are hospital stockpiling, resource protection and insurance problems in the context of preparedness. Haphuriwat and Bier (2011) examined defence by focusing on the best allocation of resources, in decision making context [37]. Lai et al. (2015) analyzed flood risks by using game theory that determines weights of flood risks [38].

On the contrary of lots of theoretical approach over preparedness, there are only a few practices. Because of the fragility of community, organizations and any kinds of relational groups during disasters, there is a considerable need to develop practical approaches as well as theoretical ones. Now it is going to be considered some examples of practical approaches in the U.S.A, E.U. and Turkey.

Pre-Disaster Management Practices in the United States

One of the practical approaches that has been established by The University of San Francisco as a plan to prepare its community for potential disasters. It includes from suspicious packet to the bomb threat, from earthquake to infrastructure failure [39]. In these preparations, the focus is to educate community in order for them to behave most effective when disaster occurs.

The American Red Cross is another example that provides emergency assistance. In this organization there are some plans for families, children, adults, workplaces, schools and people with disabilities [40]. Because the age group of people and the place of people in which they can face with disaster is important and these places require different sorts of precaution, it can be said that such classification over disaster preparedness is necessary. This organization mainly focuses on education and materials that victims may need. For instance, there is a Red Cross Store in which any kinds of kits can be found which plans mentioned above can be read.

Pre-Disaster Management Practices in Europe

In order to assess how and in which respect the E.U. members are ready for disasters, survey was conducted in all 27 members of E.U. One of the aims of this survey was to understand in which elements E.U. need to develop and focus more on [41]. The elements of disaster preparedness and their capabilities are shown at Figure 2.5. Respondents were asked whether the elements are acceptable or not.

As it can be seen from the result of the survey, nearly %85 of all respondents is satisfied with available health information element and regional disaster plans. However only almost %55 of the respondents are satisfied with the available hospital conditions and education and training element. Even though these two elements was considered as a traditional elements, there is no insufficient element with regards to preparedness.

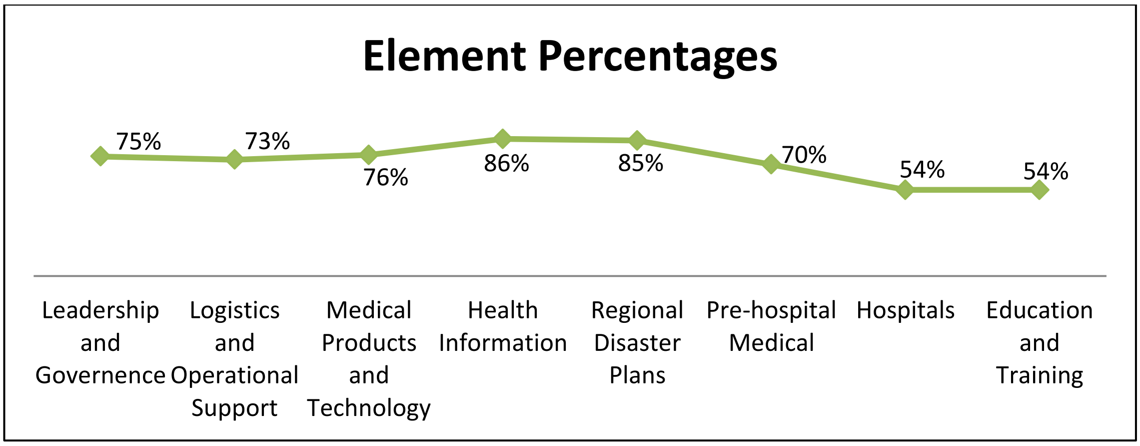

Figure 2.5 Preparedness level of different element of disaster management systems in European Union [41]

As an example of disaster management practices in Europe, The French Vigilance System (FVS) is known as a good practical one. The system was gradually developed between 2001 and 2011 after two major storms killed 92 people with monetary damage of 15 billion euro in 1999 in France [42]. French government and French meteorological service Meteo-France worked together for this project. First action was to overcome legal limitations when disaster occurs. Then it becomes mainly forecasting and early alert process that includes the disasters related to meteorology such as, thunderstorm, flooding, snow-sleet, heat waves etc. The multi-expert mechanism process of this approach is shown at Figure 2.6. As it can be seen, there are some different mechanisms working together such as civil defense service, media or forecasting center. Data created as a report is taken, in the process, from Meteo-France and Civil Defense Service as a daily brief. Information gathered as a part of the process includes health reports, index of past experiences, rainfall statistics and flood parameters as well as information taken from radars.

Pre-Disaster Management Practices in Turkey

Because of the geography, location and climate of Turkey, there are a huge number of disasters occurring each side of Turkey every year, from earthquake to landslide, from flooding to drought. In order to overcome these difficulties, Disaster and Emergency Management Presidency of Turkey (AFAD) created lots of projects as a preparedness stage for disasters, one of which is a disaster training center [43].

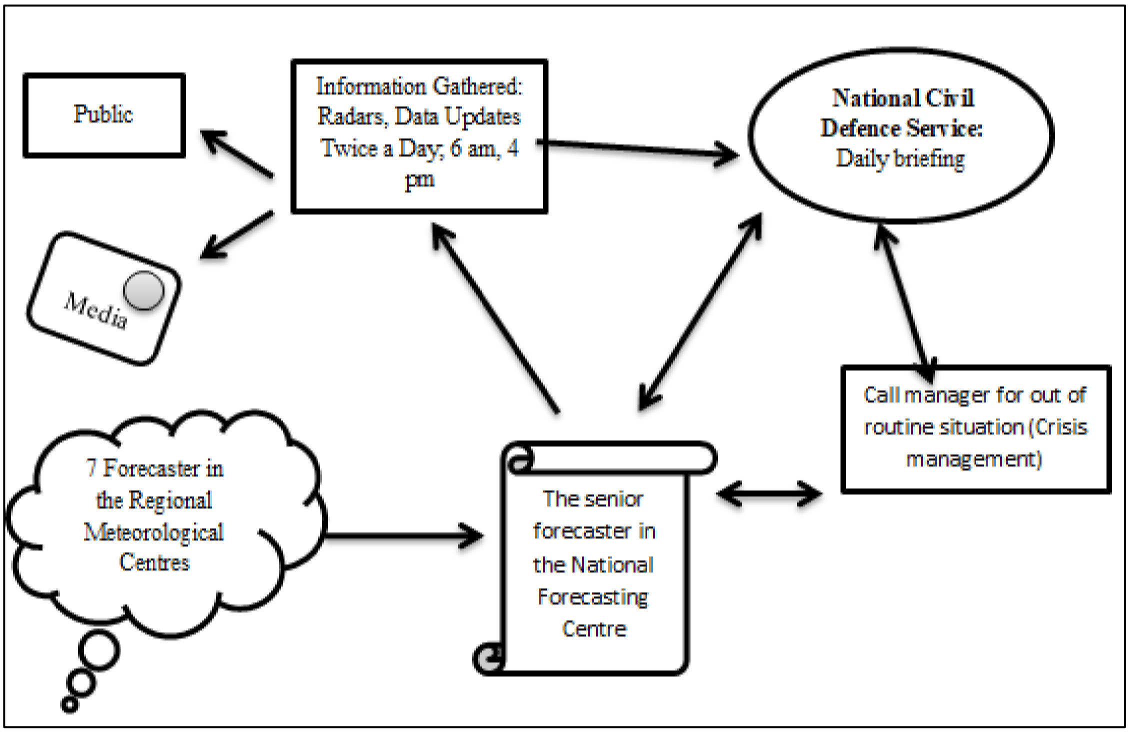

Figure 2.6 Multi-expert process of disaster management process [42]

Another preparedness stages of it is an Integrated Multi – Hazard Early Warning System which is worked when nuclear actions, drought, earthquake, wildfire or flooding occur, by using sensors, cameras, satellite or UAV images for forecasting. After receiving unexpected event, warning and reaction process start as it is shown at Figure 2.7. AYDES in the figure indicates Turkish Disaster Management and Decision Support System Research and Development Projects which is the key part of the process. It includes imaging with UAV, dissemination software, decision support, GIS, remote sensing and early warning.

Another practical activity is taken by Bogazici University, by establishing Disaster Preparedness Education Unit (DPEU), allowing people to educate themselves by participating this system. The aim of DPEU is to develop awareness and to teach how to use materials that people may need during disasters. As an example of such training programs, in 2011, DPEU has provided “Eartquakepark” [44].

Apart from that, directorate general for State Hydraulic Works (DSİ) has presented a flooding response information system named TAMBİS, provides an application on Android and İOS aiming to gather in database and to control all activities that was detected by personnel or public in order to response in effective and timely manner [45].

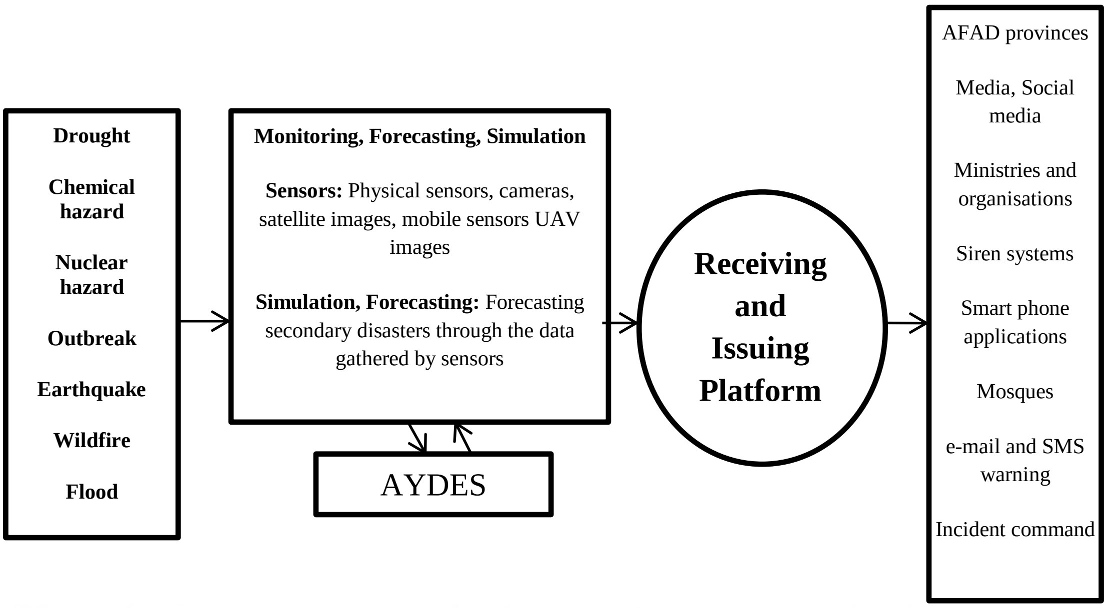

Figure 2.7 Integrated early warning system of AFAD [43]

2.4.2.2 During Disaster Management: Response

The second period of disaster management is named as 'during disaster'. In order to reduce losses, damages and tolls, acting phase is known in disaster management as a 'response' phase. As the first 40 hours after the occurrence of disaster is crucial, this period could be regarded in response phase [46]. It is clear that decent time of respond could save lives. So as to reduce the time of respond, it becomes crucial to develop planning and sharing critical information section as some parts of disaster management response stage. There is a need for each individual within community to response disaster and to achieve this aim, it is necessary for people to notice the sign of disaster as soon as possible.

The response phase of disaster management is a context that happens just after a disaster occurs. It includes any activities to hold in order to decrease damages caused by disastrous event [36]. Figure 2.8 shows a summary of subtopics of disaster response phase. To understand how the respond mechanism works and how can it be developed, Thieken et al. established three data groups with some differences in which people were experienced flooding in 2002 and made a survey. 26.8 % of the participants mentioned that flooding was unexpected for them and they were not received any warning. As an answer of a question 'Why you did not perform emergency measures?' 65 % of them said it was too late to do anything [47].

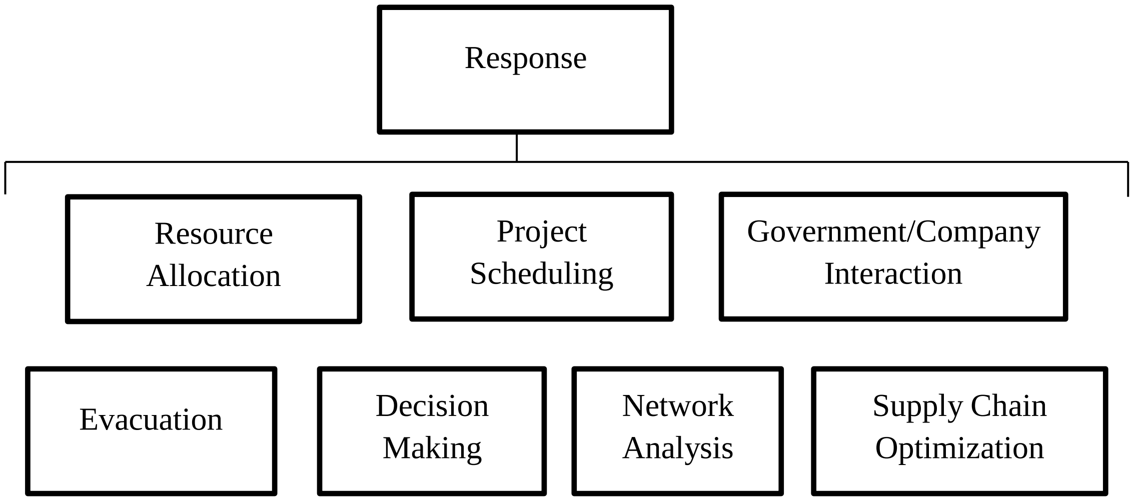

Figure 2.8 Disaster response phase subtopics [36]

As an example of cooperation in disaster response phase, Yang et al. (2008) analyze cooperative games to schedule deliveries and necessities to emergency locations [48]. In that study nodes of transportation acts as a game player which have abilities to transport resources to certain places. Another example is the study of Smyrnakis and Leslie (2010) in which they apply stochastic fictitious play model for disaster response phase by focusing on response time and effectiveness [49].

Response practices in the United States

In the United States, Federal Emergency Management Agency (FEMA) conducts a significant number of projects and practices regarding response phase in disaster management. There are FEMA emergency response vehicle teams; some of them are located at even shopping malls [50]. National response coordination centers are located in many state of country.

Besides, there is a Geographic Information System (GIS) services in FEMA and in order to disseminate information during disasters, Geospatial Standards of Operation (SOP) document for GIS workers are prepared [51].

Public Health Emergency (PHE) is another organization with the aim of assisting community in disaster preparedness, response and rehabilitation for any kind of disasters. It mainly focus on planning, procurement, countermeasures and strengthen operational and hospitals’ capabilities [52]. Elapsed time of disasters differ by type, such as while drought may continue for three months, earthquakes most of time lead for minutes which make it difficult to have one type of response mechanism for all type of disasters. In order to respond rapidly, The Office of the Assistant Secretary for

Preparedness and Response (ASPR), which is one part of PHE, uses social media mainly Facebook and Twitter that could steer emergency team to work in most effective way during disasters [53].

Response practices in Europe

In the United Kingdom, for example, there is an Emergency Response Team Search and Rescue (ERTSAR), working 365 days 24 hours with their boats and technical equipment. There are some training programs spending a full day on a river with practicing boat maneuvers and rescue techniques [54]. Such programs help the member of the team to keep their skills at top making them fit to disastrous situations.

Another example is European Assistance Team, as a part of EURACARE project with the aim of developing multinational team for European citizens. This team is able to respond in the area of evacuation by not only providing medical but also psychosocial and logistical support [55].

Response practices in Turkey

There are several response mechanisms and organizations working on Turkey, one of which is Search and Rescue Team (AKUT). There are 36 teams working in different areas of Turkey related to AKUT. Between 1996 and 2015 AKUT teams have rescued 2305 people and 989 animals. 408 of people have been rescued from flooding with %17.7 of total, during 20 years [56].

On the other hand, Disaster Coordination Center (AKOM) in Turkey works effectively on for decreasing the negative impacts of disasters. In order to respond most quickly to disasters with the need of first aid, social services, fire protection, food, transportation and so on, there is AKOM information and planning services. As an example of AKOM's works in Istanbul in Turkey, 28 icing early warning system was established. Sensors put at the heavy traffic areas helps to get information about time and the thickness of ice, then calculating the necessary salt quantity and the ways of the vehicles which brings salt as quickly as possible. These aids reduce the expenses as well as reducing discomfort of citizens. AKOM have 1664 staff and 532 vehicles for emergency situations with the planning and guidance mechanism [57].

2.4.2.3 Post-Disaster Management: Recovery

The third period of disaster management is known as ‘Post-Disaster management’. Post-Disaster management phase could include economical, legislative, technical, infrastructural, social and relief stages [58]. It could also be regarded as reconstruction, decision making, and cooperation of stakeholders in recovery phase [36].

It is clear that disasters can change humans lifestyles utterly in which it occurs. İn order to sustain each people’s life, there is a strong need for recovery. Recent developments for planning and sharing information can contribute to reducing the time and effectiveness of recovery. However, what does actually the recovery mean?

In terms of cooperativeness or game theoretic approach over disaster recovery phase, for example Horiuchi (2012) examined following disaster phase in terms of hawk-dove game. When resource are more important than values comes from fighting, cooperation becomes dominant strategy [59].

Apart from these, there is a fragile line between speed and deliberation in recovery phase. Platt and So addresses that in Turkey after the Van earthquake speed was main perspective on disaster [60]. However, in order to achieve sustainable reconstruction there is a need for deliberation and convenient recovery planning. Despite the fact that disasters are ubiquitous; because of the cultural, economic and geographical dividedness, there are different views in different countries regarding post-disaster management.

Recovery Practices in United States

There are several types of disasters occurring in the U.S., however, with regards to monetary losses from 1960 through 2009, hurricanes, flooding and coastal hazard, severe weathers are having %74 of all type of natural hazards, as it is shown at figure 2.9. Hurricanes cost 147 billion dollar with the highest percentages of monetary lose between these years while it is 144 and 132 billion dollar respectively, that of flooding and coastal hazards and severe weather. From 1960 to 2009 total monetary loses is 572 billion dollar with regards to disaster recovery practices in the U.S. [61].

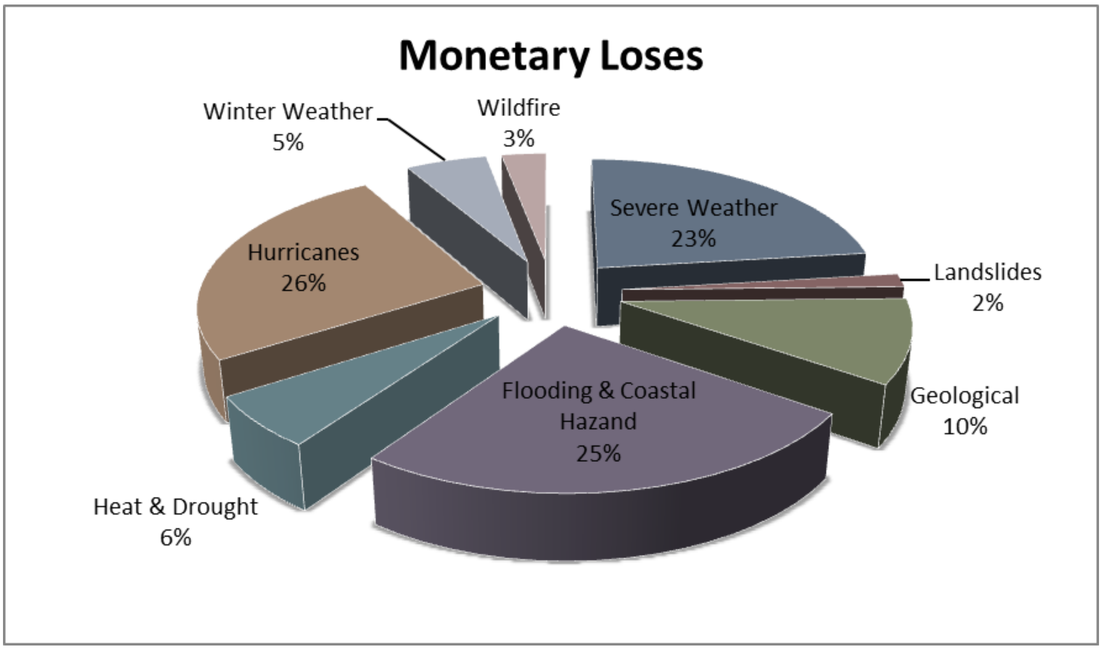

Figure 2.9 Monetary lose percentages from 1960 through 2009 by type in the U.S [61]

Because of the huge ratio of hurricanes, flooding and coastal hazards, severe weather; disaster management works are focusing on mainly for these types, including post disaster management in the U.S.

It is clear that similar to any other country; emergency laws were first things to be considered in order to recover as fast as possible in the U.S. After having decent laws for disaster management, it becomes necessary to have appropriate plan for post-disaster management. In figure 2.10, it is shown transportation and land-use planning model of Hocanson, which includes computer modeling for land use and transportation after disaster with historic data [62]. Plan and data mosaic of this model consider the effect of disaster scenarios, new patterns of streets and metro ways, transit and land use opportunities and mitigation. This structure of planning is used by government arrangements for nearly every U.S. County.

For recovery, there is a need for action from economical, health, development, construction, transportation sectors. There is also Long-Term Community Recovery (LTCR) team of FEMA working for such issues after disasters. Besides that, planning section is the key part of recovery actions with the use of past experiences [62].

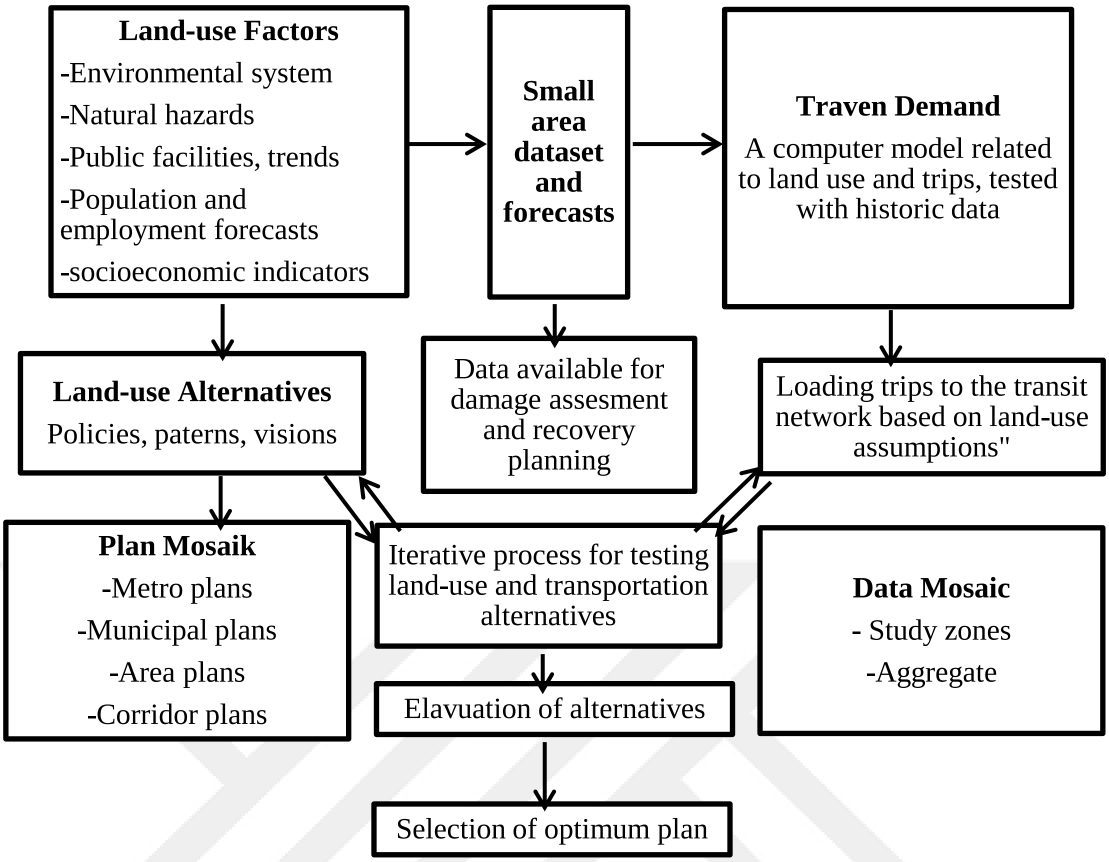

Figure 2.10 Transportation and land use planning for disaster recovery [62]

Recovery Practices in Europe

With regard to European countries; earthquake, flooding, extreme temperature and storms are the mostly effective disasters occurred between 1980 and 2008 [63]. Because of that, disaster recovery phase are developed with the focus of such hazardous events.

There is a risk and recovery mapping services focusing on past events by using satellite images and it could help the area of disaster occurrence. The service was developed under the Copernicus Emergency Management Service. There is an activation tool for some disasters and these activations are serving more knowledge about European countries which experienced strongly destructive disasters [64].

Global Facility for Disaster Reduction and Recovery (GFDRR) is a group working worldwide in order to improve timeliness and quality of recovery for more than 50 countries [65]. Denmark, Germany, Austria, Italy, Sweden, Switzerland, the United Kingdom and Norway are European member of the organization.

There is a Post Disaster Need Assessment (PDNA) team working on needs after disaster. The scheme of resilient recovery of PDNA is shown at Figure 2.11. As it can be seen there are three part of response; short-term represents for response within a week that of intermediate is from weeks to months that of long-term could lead for years [66].

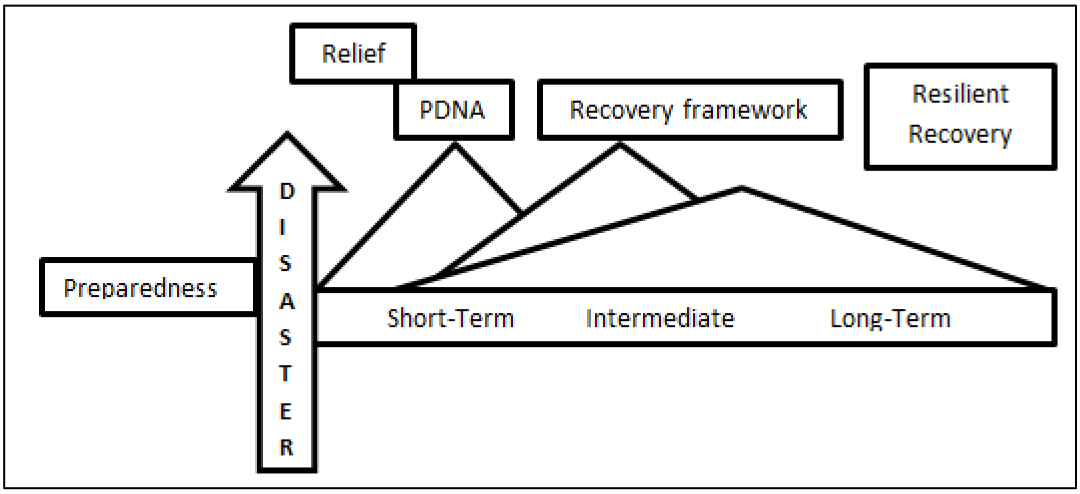

Figure 2.11 Post-disaster resilient development [66]

As PDNA is the feeding point and hearth of the system. The core elements of PDNA are;

- Pre-disaster context and baseline information: examining social, economic, cultural conditions in the pre-disaster context,
- The assessment of disaster effects and impacts: assessing the effects of disaster and the value of these effects; determining the impacts of disasters such as economic changes,
- The Recovery Strategy: determining sector recovery needs [66]

An example of needs for post-disaster is shown in Figure 2.12. The quantitative data is gathered from PDNA assessment of disaster effects. 'Other' in the chart represents for housing, urban water, health, education, industry, tourism, trade, electricity, rural water and hydromet [67].

Recovery Practices in Turkey

Recent disasters showed that in Turkey, recovery phase had been limited with emergency rescue team and providing basic needs such as food and health care. After being affected by several types of disasters, now, building temporary houses, providing social and psychological rehabilitation is also included in recovery phase.

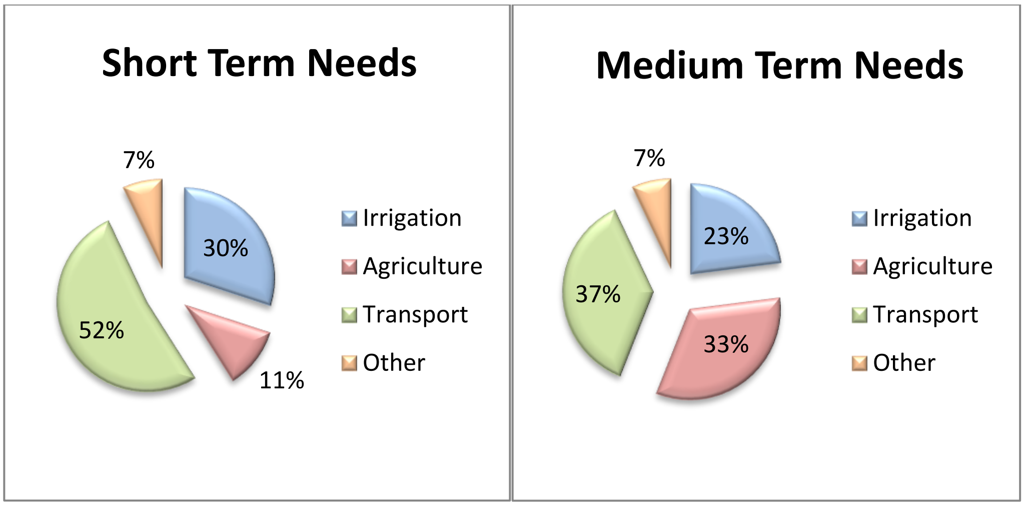

Figure 2.12 Short and medium term needs after disaster [67]

Another activity that is developed in Turkey, in order to help the decision makers, governments and ministries in all phase of disasters, is named as Turkey Disaster Information System (TAMBIS). In this GIS based disaster management system, it is become easier with modern technology to achieve some distinct outcomes. This method could be used in planning for recovery and response phase even before disaster occurs [68].

Even though there had been little decision makers, stakeholders and community involvement in post disaster planning phase of AFAD, with the new perspective on disaster, the involvement of them is being increased with 2013-2017 strategic plan of AFAD [69].

As a result of all practices, Altay and Green (2006) listed typical activities in mitigation, preparedness, response and recovery at [7], which can be seen at Table 2.2.

2.5 Risk Management

Risk management in general is a concept that has been taken attention over the last few decades [70]. It was first related to management of health and safety, environmental or economic risks [70]. Now it is seen as an important topic in controlling disasters, as a part of disaster management.

Table 2.2 Typical activities of disaster operation management [7]

Mitigation	Response
• Land use control to decrease occupation of high hazard areas • Barriers for deflection of forces • Active measures to prevent developing situations • Developments of building codes • Tax related measures • Control of reconstruction measures • Extreme events risk analysis • Insurance strategies	• Emergency plan and operation center • Evacuation measures to endangered population • Medical care to the needed • Fire obstruction measures • Search and rescue actions • Recovery of lifeline fragile services such as infrastructures • Management of fatality
Preparedness	**Recovery**
• Recruiting personals and vehicles for emergency activities • Emergency planning • Aid agreements • Training of residents and personals • Education of public • Acquiring necessary equipment • Maintenance of emergency supply • Developments in communication network • Disaster exercise to personals	• Cleaning up debris • Financial helps to sufferers • Restoring and rebuilding critical elements, roads and bridges • Full restoration of lifeline services, infrastructures • Mental support to sufferers

The definition of the term “risk” varies from subject to subject. However, in general, it is accepted that risk is the probability of loss depending on mainly three elements: hazard, vulnerability and exposure. Change in any of them could directly change the quantity of risk in the subject [71]. It can be said that function of probability and impact can form the term risk as well. In order to have appropriate risk management approach, there is a need to define all risks then the weights of them should be measured, afterwards management phase could be worked.

In order to make optimum decisions, all risks should be analyzed in the related areas. If there is a risky condition, it means there is a probability. If a risky event occurs, then it can be said that there must be some consequences of it.

In terms of flood risk, there is no unique definition of it, as one of them would not satisfy all different sorts of risk managers. Kundzewicz and Takeuchi (1999) addresses the key elements of flooding as; physical properties of earth's surface such as rainfall and snowmelt, drainage and flood protection systems, economic social and environmental properties in flood danger zone, organizations and institutions with their responsibilities, insurance companies, and a range of stakeholders [72]. In general flood system includes the physical process of it, the inhabitants of flood prone areas, infrastructures, ecosystems and all sort of people that influenced by flooding or having impact of it [1].

In terms of flood risk management, there are not only hydraulic and engineering aspects of it, but also social, economic and environmental aspects [73]. Flood risk management consists of data gathering, risk assessment, evaluation of options, implementing decision making processes to decrease, control, accept or distribute flood risks [1].

Apart from that, in order to have appropriate flood risk management approach, there are lots of institutions so-called stakeholders such as urban planners, municipality engineers, flood management organizations, civil defense authorities, academic institutions as well as health and social service employees [73]. It is obvious that no single institution is responsible for flood risk management. Each institution generally conducts its own works. However, local municipalities are the key elements for the success of flood management mechanisms. Key success factors to do it so are; clearly assigning tasks to either inner departments or involved institutions. Both overlapping and non-assigned responsibilities prevent effective and sustainable flood management. Another point is the content of policies and plans, which should be clearly stated and with high workability. Moreover, without doubt, financial condition and the capacity of an organization are also vital to manage with flood disasters [73].

Integrated solution of flood disaster includes relationship between different flood management measures, the analysis of cost, time or effectiveness, consisting of all stakeholders, their utilities and actions in social, environmental and economic context [1].

As it is obvious that flood damage cannot be avoided purely, the aim is to decrease social, environmental and economic aspects of it. To have overall control over flooding, Tingsanchali (2012) addresses that three concepts should be integrated which are; integrated flood management, total water cycle management and land-use planning. [73]. Because of more accurate determination of economic impacts of it, over the last decades focus was more on the economic impacts of it. However, from the economic approach to multi attribute including human distress, social and ecological impacts of it are done for achieving integrated solution [1].

In general flood risk management includes several type of interventions which are controlling overflow and developments of floodplains, operation and maintenance of flood defense mechanisms, operation, maintenance and management of drainage systems, early warning developments, accurately forecasting and so on [1].

2.6 Flood Disaster Management

It is clear that water has the power of destruction but the sense of water is mostly regarded as a positive substance for many people. Water does actually not resist, it flows.

As water is described such a positive way, it can be easily said that water cannot consists disaster itself; it actually is a powerful beauty. However, flood disaster could be regarded as a disaster that occurs because of vulnerability and misdevelopment. By having control over water flows, water may not be wasted and such destructive leading to disasters.

Because land is more fertile, in many places over the world, people tend to be located in flood plains. Because of high urbanization, impervious areas in cities are increasing which prevent water to infiltrate into soil. Such impacts causes increase in runoff depth resulting in flooding [73].

In literature, different sort of flood disaster management strategies are applied to hundreds of studies. Ruin et al. (2002) studied the effects of flood disaster in terms of fatality and injury numbers to understand physical parameters of flood in different time zone and different exposure of rainfall [3]. Spitalar et al (2008) also worked the flash flood parameters by focusing on number of injuries and fatalities [74]. Jonkman and Kelman (2005) examined the causes and circumstances of flood disaster deaths by focusing on thirteen flood events from Europe resulting in 247 flood fatalities [4]. Chang et al. (2008) examined 5 representative cities in Korea to find the responsible for increasing flood risks [75]. Hall et al. (2003) addresses that only with an integrated flood risk management, which requires relationship between all stakeholders and risk management measures, the analysis of them in terms of cost and effectiveness within social, economic and environmental context, sustainable flood management can be achieved [1]. Price and Vojinovic (2008) highlight the importance of integration between storm water cycle urban flooding in order to decrease urban flood risks [76].

Radmehr and Araghinejad (2014) developed spatial multi criteria decision making tool to understand the mechanism of necessary data and criteria, so that the decision making process can be hold in the context of urban flood management [77]. Dang and Babel (2011) studied on flood parameters in terms of flood hazard and vulnerability then weight them by using AHP process to examine effect degree of these parameters [2]. On the other hand Dwyer et al. (2004) analyses social vulnerability parameters for disastrous events from household types to health level, from gender to tenure type [78]. Costa et al. (2004) describes multi criteria analysis for evaluation of flood control options, by giving quantitative evaluation model depending on qualitative value judgments [79]. Scheuer et al. (2011) illustrate an approach to model multi criteria flood disaster vulnerability integrating economic, social and ecologic risks, starting from multi criteria risk mapping [80].

In monetary terms, flood loss estimation was studied by various authors including Dutta et al. (2002) [125]. Smith (1994) worked on the assessment of flood losses which requires stage-damage curves for different type of buildings [81]. Eid et al. (2015) examined game-theoretic attitudes of residents and insurance companies as well as federal disaster response team in order to distribute funds to more in need [10]. Eid and El adaway (2016) developed an agent based model to implement economic vulnerability assessment tool, different stakeholders’ strategies and their learning mechanism by focusing on three Mississippi coastal counties [82]. Kelman and Spence (2004) presents flood characteristics by focusing on flood damage on buildings [3]. Ahmad and Simonovic (2000) examined the capacity of reservoirs in flood events with sensitivity analysis [83].

Apart from the general outlook on flood management options, in most of the studies GIS (geographic information system) was used to illustrate either flood risk or flood vulnerability maps.

Over the last decades, flood management approaches and models have focused on economic aspects and consequences more, while social and environmental aspects of it have not been taken into account that much [84]. Actions were tried to achieve in real time, however, prioritizing these actions, which action should be taken first, second and so on, in order to get most beneficial outcomes remain as a core question of flood action plans.

2.6.1 Classifications of Flood Events

According to Oxford dictionary, flood is defined as 'an overflow of a large amount of water which is more than its normal limits' [85]. The types of floods addressed by Jonkman are suitable to this definition. For him the main types of flooding events are; coastal floods, flash floods, river floods, tidal waves, tsunamis and drainage problems, in which flash flood has the highest percentages of mortality [86].

However, from the light of the definition of disaster, in order for flood to be defined as a disaster, there needs to be a sufferer, or damaged to infrastructure, farmlands, or any sort of properties belonging to people or any institutions.

Douglas et al. classified urban floods in four types which are; due to insufficient drainage, from small streams in the built environment, flooding from major rivers, and coastal flooding [87] while Boardman et al. distinguishes floods as winter and summer floods [88].

Nied et al. classified flood events as; rain-on-snow flood, snowmelt flood, long-rain flood, short-rain flood and flash flood with six flood type indicator which are; spatial flood extend, seasonality, snow cover, air temperature, precipitation and length of built-up period [89].

Apart from these, loss estimation for different type of floods were analyzed at [90], which are; floods due to increase groundwater level, slow-rising riverine floods, flash floods and, floods due to dyke breaches.

FEMA addresses that the most experienced flood types are: riverine, coastal and shallow floods. Flash floods and overbank floods are also one of the other types of flooding [91].

In terms of urban floods, it can be classified as events because of heavy rainfall, river stream, high tides or storm surges [73]. In this study all urban types of flood events were included as well as dam break floods. However, focus is more in heavy rainfalls than others because of the increase in heavy and short rainfall as a result of climate change, which cannot be predicted easily [73].

2.6.2 Concepts and Consequences of Flooding

In order to make flood disaster more clear, there are some concepts that need to be illuminated.

Hydrologic cycle, for instance, is a core of flood events, and it is also known as water cycle. It is a continuous interchange of water between water sources, land and air, evaporation, precipitation, transpiration, condensation, runoff and infiltration. Management of flood disaster or water sources actually is a grasp of this water cycle [92].

Floodplain is another crucial concept that is needed to be defined. It can be defined as; flat valley consisted of sediments deposited by the water flowing over the stream beds [93]. Human occupancy of such places is making it harder to control flood events. It is addressed at [94] floodplains have been created as a result of deposition of fine grained materials over many tousands of years.

Sedimentation is another vital concept related to flooding, which actually starts with erosion, transportation and deposition of sediments by water flowing with different velocities [95].

Basin is an area which drains its water into a lake, sea or any other water bodies which is also known as watershed, catchment area or drainage basin [91].

When flood damage is concerned, it can be said that it effects on built environment rather than natural environment. The term built environment is now needed to be defined. The term refers to features of the area surrounded by human and activity of humans, differentiated from natural environment [96]. The Construction Industry

Council addresses that the term includes all type of buildings, infrastructures and managed landscaped between structures [97] in which flood impacts.

In terms of consequences of flood disaster, it is clear that, flooding is one of the most destructive disasters in the world, with the average death of 3000 people per year between 1975 and 2002 [86]. Recorded death and health problem quantity could show anybody how destructive flood events are. However, it is not enough to have information about deaths and affected people directly after a flood occurs. The long term negative impacts of flooding was investigated and it was found that, by focusing on twelve months period of 1968 Bristol flood after it occurs, population mortality rates increase by 50% in flooded part compared to non-flooded part of the city [98].

Moreover, the loss of flooding cannot be limited with the number of deaths or injuries, there are a huge number of loss types apart from mortality, some of which are worsening to infrastructure, agricultural productions, socio-economic welfare and the value of historical places [99]. It can be said that, such kinds of losses could be regarded as a social and economic losses.

In terms of economic losses, flooding costs 312 billion US dollar between 2004 and 2013, in other words it costs nearly 31.2 billion US dollar every year, which equals to nearly 20% of annually losses of all kinds of disaster, which is nearly 164.2 billion US dollar, for that 10 year period. Besides, average flood losses have become nearly 52 billion US dollar per year between 2010 and 2013 [100]. From the light of above, it can be said that monetary losses will probably continue to increase for the next years.

Because of such effects of flood events, there are hundreds of ways that human beings are building or developing in order to reduce the negative impacts of it.

2.6.3 Developments in Flood Disaster Management

Flood disaster management, similar to other types of disaster, has three different levels of actions: an operational level, a project planning level which is used when a revision of an existing project is needed, and a project design level aiming to reach an optimal solution to the general management [101].

A conceptual framework for general flood disaster management is formed by World Meteorological Organization (WMO), consisting of three general concepts, which are integrated flood management (IFM), land-use planning and total water cycle management (TWCM). IFM concept is mainly based on land and water resources development, aiming to effective use of floodplains and integrating land and water management. Besides TWCM concept is based on storm water management, water supply and sanitation associatively whereas land-use planning concept calls for integrity of land use plans and flood management plans [102].

Apart from that, there are mainly three flood disaster management phases as it has already been mentioned which are pre, during and post disaster management basically. In following parts pre, during and post disaster developments will be examined dividedly.

2.6.3.1 Pre Flood Management Developments

Flood preparedness stage in any respect is aiming to reduce the risks of flood, besides; individual preparedness is the core element for that. Coulston and Denny indicate the importance of flood preparedness, by focusing on differences between two cities which experienced the same flood effects in 2007 in the United Kingdom, but had experienced different rate of flood. The result showed that the respondents experienced flood more frequently was prepared more [103]. As there are a lot of things to do for individuals to prepare themselves to flooding, most of countries have worked necessities of it.

When pre flood management is concerned, early warning systems are one of the other main approaches, in order to reduce the negative impacts of it. Spatial sensor-based models are mainly used for such mechanisms and it requires in detail: soil composition, topography, land cover parameters and meteorological information [104]. Basha et al. tried to create flood management application by combining four phases which are computer communication network, special-purpose and application-based systems, simulation and modeling, and physical science, engineering; which are presenting network architecture, embedded systems, model development and atmospheric conditions respectively [105]. Pappenberger et al. suggest that with adequate implementation of early warning system, avoided damage of flooding could increase by nearly 32 per cent in economic respect [106]. Though there could be some false alert, avoided damage profits can easily compensate the negative impacts of such alerts.

Mapping is another kind of approach over flood risk reduction that is mainly developed to understand which areas are prone to hazardous events. Mainly, there are four types of flood mapping which are danger map, hazard map, vulnerability map and damage risk map. However, damage modeling, in the context of flood, has not received enough attention because of the weakness of theoretical and empirical data and the reliability of the data [107]. Today, such kinds of risk maps related to flooding are also drawn with the consideration of Geographic Information Modeling (GIS) combined with topographic information.

2.6.3.2 During Flood Management Developments

Even though there are different sorts of flood types, main actions considered during disaster is to move sufferer to safety places which are high enough that no flood water can reach [101]. In order to solve such problems, there are hundreds of works being done. As one of them, planning developments when flooding occurs, with the concept of transportation, Chang et al. proposed a model addressing logistics preparation problem under uncertainty in order to have appropriate rescue plan, which include three main steps: generating map layers, analysis of map layers and data analysis, and output, aiming to determination of rescue resource distribution system of flooding [108]. It is clear that creating an appropriate rescue team, which could meet all types of necessities of victims, is crucial in flood management. Almost every country has their rescue team to act when disaster occurs. However, as an example of developments of such rescue teams, a study has been done by Bernard et al. focusing on aerial robots as rescue team members. Unmanned aerial vehicles (UAV) were used as a test. Even though one vehicle can carry just a few loads, when it becomes vehicles team, working as multi agents, they could carry more. For instance 3 UAV carried 4,5kg load with interacting each other. The vehicles can fly in medium wind conditions as well [109].

2.6.3.3 Post Flood Management Developments

Post disaster management, in terms of flooding, can be divided into four phases which are: emergency, restoration, reconstruction and betterment reconstruction [110], while emergency phase could also be regarded as a response phase. These four steps are related to each other respectively. When flooding occurs, emergency phase starts and increases, after some time, depending on magnitude of flooding, emergency phase activities decrease and with that restoration phase starts. The processes continue for each successor. As a last phase, after declining the actions for reconstruction, betterment reconstruction starts, which is related to developments of reconstruction phase.

Some of the activities that should be done in this respect includes procurements of basic necessities for victims such as mobile electrical substation, mobile equipment, automation system installation, mobile flood protection walls, determination of vulnerabilities on flood plains as well as food and water supply [111]. It also includes rehabilitated channel drainage systems and water pump stations. Besides, rehabilitation of damages caused by landslides affecting transportation network was also one part of the process.

As recovery process involves different sort of activities in different disciplines such as resource and time management, restorations, funding arrangements, regulatory and reconstruction, it requires coordination of all stakeholders. It can be said that, recovery phase of flood disaster focus mainly on converting the lives and properties into its normality and decreasing the level of vulnerability for future events.

2.6.4 Vulnerability to Flooding

Vulnerability can simply be defined as an inability to manage with any type of events. More profoundly, Adger describes it as "the presence or lack of ability to resist shocks and stresses to livelihood" [112]. Chambers addresses that vulnerability is not a concept of lack; it is more exposure and defenselessness [113].

It can be said that vulnerability can vary by person in terms of economic, environmental, social and cultural factors. The definition of it could also be changed by type of events. In terms of flooding, low-income people, migrants, people living in flimsy houses, those without insurance and the elderly are, without doubt, generally the most vulnerable ones, which could be regarded as individual or collective vulnerability.

It is obvious that increase in disparity in income and asset distribution results in the increase in vulnerability when flood occurs. Apart from that it is not only people who are at risk, their properties, infrastructure or any sorts of facilities have also their vulnerability level.

It is clear that the level of vulnerability to flooding has a huge impact on local and national economies; however, it is hard to combine them and have appropriate integrated results. To evaluate the economic outcomes of vulnerability to flooding, Van der Veen and Logtmeijer studied on South-Holland, which is the hearth of the economy of the Netherland, with ArcView GIS 3.3 software by determining the economic hotspots. The simulation of the study between Den Haag and Rotterdam shows that the economic hotspots are not situated inside the flooded area; they are mostly situated on the border of the flooded areas [114]. This could increase the vulnerability because infrastructures could be heavily hit by flood; highways, electricity and gas lines could be damaged enormously. Such results indicate the importance of integrated flood management systems by focusing on vulnerable places, not only the flood risky areas.

In order to decrease vulnerability, there are structural and non-structural measures that can be done, such as public education, insurance interventions, implementation of regulations, warning systems and catchment interventions and so on [115]. There is a strong need of determination of all factors increasing the degree of vulnerability in the context of built environment.

CHAPTER 3

RISK FACTORS AFFECTING FLOOD LOSS LEVEL

As flood disasters are increasing all over the world, so do the necessities for appropriate flood management systems in urban areas. Determination of risk factors and impact degree of them are crucial to achieve relevant information and management mechanism for flood disaster. In this part of thesis determination of urban flood risk factors will be presented.

As there are a huge number of main and sub factors related to urban flood events, narly 50 papers, by focusing on 35 of them, were investigated to gather all type of factors affecting flood loss level. In general, there has been found 74 factors that could change hazardousness, destructiveness and characteristics of flooding as well as vulnerability of the community. 11 main factors were determined which contains these 74 sub factors, in which 4 of them are flood hazard risk factors and 7 of them are risk factors affecting built environment. Weather conditions, environmental, basin characteristics and flood characteristics factors are flood hazard risk factors while institutional capacity, urban infrastructure, land use, superstructure capacity, demographic and social, ecological and accessibility factors are factors affecting the vulnerability of built environment. The factors and their definitions are listed below. Even though some factors could be related with more than one main factor, they were tried to be suited into the most adequate clusters.

3.1 Flood Hazard Risk Factors

It includes 3 main factors determining flood magnitude, which are flood depth, duration and velocity all of which is affected by 3 main factors which are; weather conditions, land and environmental, and basin characteristics. They were embedded into this category as they have direct link to generate excessive flows, in other words flood hazard.

3.1.1 Weather Conditions

It includes such factors as temperature, air pressure, and velocity of rainfall, which can be detected by meteorological measures.

3.1.1.1 Temperature

There are several types of effects of changing temperature. First of all, it can be said that, warmer temperatures can hold more water vapor in the atmosphere and therefore they are likely to exaggerate the global water cycle which means increase in flood risk [75], [116], [117]. As increase in temperature lead to snowmelts, it makes the area more vulnerable too [118], especially in places where slope is higher [119], from another perspective. There is a case study held in order to understand the effect of flood in different time zones, at different temperatures. Even though it does not provide distinct results, it is obvious that the behavior of people can change by changing time zone [6]. The experimental data [74] shows that the month that flood occur could differ possible outcomes. According to this data, fatality events occur most in June in US between 2006 and 2012 in flooding.

In terms of storm events, occurrences of them are higher in urban areas because the surface of building in urban areas could reach higher temperature than its surroundings which could create air ventilation resulting in storms [102]. Presence of storms means increase in destructiveness during flooding. With regards to buildings' strength, water temperature during flooding could affect on it because of the consequences of chemical reactions [3]. From the light of above, it can be said that in most cases increase in temperature could increase flood events and its negative consequences, but in terms of during flooding, decrease in temperature could lead to more devastating outcomes.

When the average temperature is concerned, as increase in globally, its effects on climate change can increase too, which could facilitate the severity of extreme weather conditions and therefore it could increase losses related to flood hazard by increasing magnitude and frequency of floods [5], [102], [118]. Estimation process related to weather could become more uncertain and unpredictable with such changes in climate [102], [119]. Wallington H. R. considers climate change as defense deterioration agent in future flood risks [70]. By considering these all, increase in average temperature is seen as a trigger of flood events and could increase directly its destructiveness.

3.1.1.2 Air Pressure

In terms of air pressure, as increase in air pressure inevitably increase the quantity of molecules per volume so do increase in rebounding of water molecules to the air, evaporation could decrease [120]. It is obvious that temperature is the element affecting air pressure most; increase in air temperature could decrease the air pressure. Besides increase in the difference in air pressure among air volumes could increase the speed of wind too.

3.1.1.3 Wind Velocity

It is obvious that increase in wind velocity over water could be swept away so do directly increase in evaporation [120]. High speed of wind can create more room for water to be dissipated into the air [121]. The average wind speed can directly impact on evaporation and sea levels [122].

3.1.1.4 Wind Direction

It is known that if the direction of wind is from the seaside to the land it could increase the humidity of air so do increase in rainfall, meanwhile the opposite is true. As the direction of wind can carry air molecules it could directly impact of heavy flood events [123]. Sepetcioglu addresses the importance of the direction of wind, by giving example of south-west of Turkey which carry huge rate of moisture. These sorts of winds could increase the possibility and negative impacts of floods [123]. Junker et al. suggest that direction of wind have a nonignorable impact of extreme rainfall events [124].

3.1.1.5 Atmospheric Moisture

As increase in moisture could be directly related to water cycle, it could have huge impact on rainfall events so do flood events. Because in the warmer temperatures the air could hold more water vapor, increase in rain events is inevitable since they could escalate global water cycle [75].

3.1.1.6 Quantity of Rainfall

Quantity of rainfall was addressed most of time in m^3 such as [6] and it could have direct impact on flooding as it feed runoffs. In order to have sustainable flood planning, there is a need for developed warning system which requires adequate information over rainfall [118], [119]. Integrating such models with fluvial flow and changes could help for integrated process [123]. It is necessary to look for a hundred years of rainfall to have effective actions [125]. There is a distinct association between quantity of rainfall and water storage in risky areas. Rapid grass growth could decrease negative effects of it [118]. However, not all quantity of rainfalls is effective rainfalls. The water in excess of soil infiltration is called an effective rainfall which is wanted to be addressed in terms of flood management [6]. From another perspective, the quantity or density of rainfalls could change the direction of flow, thus changing in exit geometry of flow, resulting in changing destructiveness of flooding [126].

3.1.1.7 Duration of Rainfall

It is clear that increase in the duration of rainfall directly increases the destructiveness of flood disasters. In built environment, rainfalls could generate high runoff because of the lack of drainage capacity and imperviousness [102]. Unexpected and long duration rain events could generate huge amount of runoff water without any control [116]. On the contrary of that, most of the flood events occur due to the short duration rains [116].

3.1.1.8 Type of Precipitation or Event

Type of precipitation, without doubt, could affect on the impact level of flooding [127]. While considering rain, it plays an important role in creating flooding, in terms of storms, as they have negative impact on human lives and their properties, when it is integrated with rainfalls, they could inevitably increase the potential destructiveness of flooding [101], [102]. Storms could exacerbate the post disaster actions too. Fatalities related with drowning could also be associated with storms in flood event [4]. They could also help to carry some perils and increase dispersing of chemicals [2]. Storms could increase the potential occurrence of other destructive events such as erosion [78] and they could result in intense rainfall leading to more extreme flooding [118]. Apart from that, storms could generate extreme flows especially in saturated basins [70], [118]. They could also increase water stresses on buildings [4].

In terms of coastal floods, storm surge could occur and increase the risky situations [75], [119]. In terms of tsunamis, as they carry huge amount of water they can cause coastal floods [102], [116], [118]. However, such hazardous events cannot be prevented by reducing the risks of flood because tsunamis are generated by natural processes [102], [118]. For this issue some barriers could be constructed near the areas which are fragile to tsunamis. In terms of snow-related actions, it can be said that, river floods are one type of flooding and snowmelts in upstream areas could increase the risk of such floods [102], [116], [118]. Snowmelts could also increase the risk of erosion [119]. Floods related to snowmelt have not been worked necessarily and it is hard to pretend it [118].

3.1.1.9 Frequency in Flood Occurrence

Frequency of flood occurrence is another factors contributing flooding and its negative consequences [3], [116]. In general, increase in frequency leads to increase in negative outcomes of flood in quantity [70], [119]. Dutta et al. used frequency method, with example in Japan, for estimating the damage of flood hazard, including intensity-duration frequency function, which is seen very practicable for flood prone areas [125]. Spitalar et al. worked on specific times of flood occurrence, and addressed that frequency of flood occurrence could change the impact of flooding in specific times as visibility of people could change [74].

3.1.2 Environmental

It includes such factors as imperviousness rate, vegetation and coastal area rate, which are more related to the location of an area.

3.1.2.1 Impervious Area Percentage

Increase in impervious area percentage due to the urban development, especially in floodplains, could clearly change the precipitation regime and the amounts of flow [79], [116] thus, decrease in the performance of drainage system [101], [102]. Land use change from more pervious areas such as woodland and vegetation to less due to deforestation and urbanization such as building roads, play an important role in increase in runoff [122]. Because of such issues, presence of impervious cover could increase the vulnerability within area, where urban areas mostly are [75], [102], [119]. Therefore, increase in flood risk is inevitable, especially if the imperviousness percentage increases near the watersheds [128]. In order to decrease the risks of it, land use change should be controlled. Afforestation is another form of decrease such problems.

By focusing on land use change, As imperviousness degree of any area could change the ‘effective water’, which is becoming runoff water or amount of runoff, changes in land cover from more imperviousness to less or the opposite one can alter the area’s vulnerability to flooding [102], [123]. Increase in land use without its natural form, especially in lowlands or floodplains, without doubt, increases flood risks [75]. There are mainly seven land cover types which are ‘dense forest, light forest, grassland, paddy, vegetables, water body and urban land use [125]. When land-use becomes more urban with deforestation and changes from pervious to impervious cover, the flow of water thus the flood vulnerability increases tremendously in both, fatality and economical terms [102], [125]. By adopting GIS based models it is now easier to have land-use mapping and thus evaluating places in which people are more vulnerable [70]. If there is an increasing trend in population of a place then land-use change is inevitable [2] and it is become necessity to take practical precautions to flooding. It goes on every time like that; which means there is a need to have sustainable development [101]. Because of the incorrect use of land, the area generating runoff could be hundreds of kilometers away from area being flooded [118]. In order to deplete such risk, there is a need for land use planning especially in flood prone areas with some precise regulatory constrains to limit developments where necessary [75], [128]. Apart from that, GIS based hydrological modeling could be used for effective land use planning [127]. For agricultural use, compaction from heavy machines for agriculture is another reason for increasing runoffs [101].

3.1.2.2 Woodland and Vegetation Rate

As trees can cut runoff waters, absorb more water, facilitate infiltration; increase in forestry or vegetation could be regarded as decreasing activity of vulnerability of flood disaster for the people [75], [102], [116], [118], especially when forestation is in upstream areas [75]. When an area once deforested, then it becomes less pervious leading to downstream floods [75]. Because of the sharp increase in population, removing the natural vegetation for urbanization could increase the flood risk as it increases imperviousness as well [123]. Removing some natural vegetation in the upper parts of rivers or water sources, have the responsibility of some of the flooding problems at the lower down of the catchments in many parts of the world [118]. Removing natural vegetation is clearly change discharges so do change in flood volume [129].

3.1.2.3 Coastal Area Rate

As evaporation is high in coastal area, there are more risks in there for rainfall events. Because of floods originated from the sea because of tidal effects, storm surges or tsunamis, areas surrounded by water are more in danger than other. Coastline configuration, depth of water along with offshore can change the intensity of possible floods [102]. Especially cities located in estuaries are more in danger as in such places riverine and coastal floods can be combined [102]. Lowering lands compared to the sea is another important factor that generates flood risks [118].

As there are some residential usage near the sea and lakes or so-called low-laying areas, increase in sea or lake water level could trigger the inundation and coastal floods [2], [75], [102], [118], [119]. Sea level rise is expected to increase flood risks due to storm surge and erosions. They could threaten infrastructures as well [102]. Water level forecasting should be adopted in early warning developments, in order to prevent such risky situations [119].

3.1.2.4 Rate of Occupancy in Flood Plain

It is obvious that flood risk become higher for people living in floodplains [127] due to the changes in flood condition directly [2], and obstruction of flows [102], [119]. Hydrodynamic modeling of floodplains could help to overcome these sorts of difficulties [75]. Another practices to decrease such risks is creating dikes [70], [118], however, the study at [101] shows that rivers are not stationary in floodplains. Land use control, providing incentives elsewhere rather than floodplains could help the solution of this problem as well [128]. Application of some regulations over this issue could be sustainable, in this respect [75], [128]. If an area will be allowed for building structures, there is a need to look for a hundred years of regime of rainfall [123]. However, it should not be obligatory; the strategy over floodplain urban development can also be developed as addressed at [128]. Developments in creating floodplain maps could also help to overcome such issues [70]. Especially ones that public creates, there is a need for public participation [128]. This factor is converted into a conditional factor as z2 at Table 3.2.

3.1.3 Basin Characteristics

It includes factors related to basins such as soil moisture level, groundwater level, basin size and shape, river discharge, and topographic and morphologic conditions.

3.1.3.1 Soil Moisture Level

The moisture level of soil of potential flooded area have clearly some associations with consequences of flood events because it could directly say something about 'how much more water that soil can absorb' when it is integrated with the type of the topography [116], [119]. The absorption capacity of soil can be changed by the moisture level of it [116]. Soil properties, especially hydrologic ones can also change the moisture level of it, resulting in differences in imperviousness [129]. Even though water desires to flow into the groundwater sources, due to the adhesion to the soil, they are not flowing directly [130].

Increase in moisture level could increase the possibility of erosion which could increase the flood destructiveness as well [6], [119]. Moreover such soil erosion could decrease the water retention capacity of soil and all type of vegetation, increasing flood risks [131]. Soil moisture level should also be included in early warning system developments [123]. Afforestation could decrease flood risk as trees absorb rainwater into soils [75].

From the light of above, it can be said that decrease in the moisture level of soil could increase infiltration so do decrease in runoff and inevitably flood risks [116].

3.1.3.2 Groundwater Level

As the main reason of flooding is the flow of water, any sort of water level could change the extent of flood event [119]. When groundwater level reaches its maximum capacity then any water could create flow thus increasing in flood risk [118]. It is obvious that if land cover allows water to be retained moisture or enter groundwater, surface runoff can decrease [118]. If the level of groundwater is high, it directly increases possible runoffs, and then flood risk is inevitable [122]. In order to have sustainable flood risk management, authorities should work on for multiple goals. In terms of flood events, for example, flood mitigation, water supply and groundwater recharge should be worked for the same purpose [102].

3.1.3.3 Basin Size and Shape

Actually, basin size is not the parameter of flooding, occupancy in stream bed is the parameter instead. Basins are the houses of water which are living as nomads. However, as increase in basin size could increase the potential occurrences of runoffs in such places, it could increase the flood risk and its harmfulness [116], [119], [123], [128]. When a basin integrates with high slopes, this could allow water in upstream areas to flow downstream by carrying sediments [116]. If a basin has a shape of circlic, then all water could reach downstream areas at the same time making the area more vulnerable, if not, water reaches downstream in different time zones resulting in less flood risks [116]. When permits of buildings are studied, a hundred year flood potential should be considered [123]. Hazard maps should also include entire river basins so that it will be possible to predict potential losses in such flood events and the basin characteristics should be determined [102]. Basin size could be considerable with respects to soil types in different parts of a basin [125]. However, Ruin et al. address in their works about September 2002 France flooding event that, most of the fatalities occurs in very small basins [6]. Characteristics [6], [128] and characteristic reaction times of basins could change by suddenness of such events [6]. In terms of flash floods, Spitalar et al. suggest that, large-basin flash floods are less common but they have much greater negative impact on people per event than in small basins [74].

3.1.3.4 River Discharge

River discharge, without doubt, has direct links to the flow of water. So, meteorological research and early warning systems should include river discharge in different places and time intervals as a parameter of flooding [119]. Fluctuations in river discharge, what high tides are affecting for instance, could lead to coastal floods [102]. As reducing the risk of high river discharges, decreasing or retention of storm water runoffs in a ‘source control drainage system’ can be embedded [102]. Peak discharge could create more incontrollable flood events due to the short times in early warnings, in terms of riverine floods [6]. Dredging or widening the watercourses could be practicable approach in order to maintain maximum discharge capacity of rivers [102]. River discharge was used by Dutta et al. in loss estimation formulas as it increases the depth of flooding [125]. Increase in river discharge and so do flow in residential areas could incapacitate some reservoirs as well [83]. ‘How much discharge of a river could create how much discharge of the flow over residential areas’ should be determined or modeled to overcome this difficulty [83].

3.1.3.5 Topographic and Morphologic Conditions

Topographic and morphologic properties of an area are one of the main factors of flood occurrences [116]. Especially when the topology is mountainous as in high elevated areas, surface runoff increases tremendously, inevitably increase in flood risks [75]. Flooding is not stationary event, it moves. In order to quantify possible risks of specific people or building, there is a need for evaluating passive actions of environmental surroundings of them. Probability of erosions is also related to the environmental surroundings of the flooded areas [2]. Differences in height between surrounding areas of flooded one is also important aspects of flood risk [116], [118]. As increase in height could decrease air pressure so do increase in evaporation, it could increase the flood risk [120]. Road cuts without considering topography is one of the reasons for increase in flood risk as well [75].

Slope is a geographical parameter which could increase the velocity of water [118], [119], [123] and the erosive moves of the snow [119]. Increase in velocity of water in general, will inevitably increase the flood risk as well. That is why Karadeniz district of Turkey encounters most of time with flood events with respect to its mountainous geography and high slopes [116], [119]. Steep slope make a low-lying area being flooded by the water coming from high elevated areas [129]. Areas with flat topography are more in danger than others [3].

Increase in slope could also increase the potential risk of melting snows [116]. Higher slope could increase the erosion probability [2], [3], [118], [119] which can be seen as another flood parameter. In general, slopes could be regarded as runoff paths [102].

In terms of type of soil, porosity or texture of it are some of the important properties of it [6]. Due to lack of adequate information about the hydrologic characteristics of different soil types [116], [115], most of time assumptions are used [125]. Nevertheless, it can be said that sandy soils retain little moisture compared to highly organic soils. So, more organic soils could result in more absorption of water and less water flow [118].

Topography and the soil type could be classified as permeable and impermeable as well [3]. In mountainous topography, for instance, soils tend to have less permeability [75]. The topography of flood plain areas has also high potentiality to create devastating impacts [70]. Changes in land-use and land cover could be detected by using GIS in this respect [75].

3.1.3.6 Entrance and Exit Geometry

Jeong and No [126] as a different sort of approach, address that the sharpness level of entrance and exit geometry of liquid could change the result of occurrence of flood, while some risky conditions can be conterted to flood events being in 'above threshold', others do not show any sign of disaster being in 'below threshold', because of the differences in entrance and exit geometry that liquid is passed. Uncertainty can also be changed by such geometry styles. In this respect, for instance, smooth entrance and exit increases the uncertainty while that of sharp decreases.

3.1.4 Flood Characteristics

These factors are flood depth, duration and flow; on which flood hazard risk factors have impact.

3.1.4.1 Flood Depth

According to FEMA, flood depth is the height of the water that creates flood events. In other words, it is the water level in flooded area [101]. It obviously contributes to the damaging potential of the flooding [75], which could be regarded as one of the prime indicators of flood [2], [101], [102] having huge impact on fatality rates [6]. Flood depth was categorized at [2] in meter, addressing that increase in depth could increase the flood destructiveness. The magnitude of flood could be regarded as function of several parameters, one of which is the depth of it [102], [118]. As slow-rise water implies high hydrostatic pressure differential, it makes buildings more vulnerable [3]. From different perspective, possible flood depth could be measured in flood plains with GIS and hydraulic models in order to estimate the damages [119], [125].

3.1.4.2 Duration of Flood

Dang et al. [2] classified flood duration into some categories in days; addressing that increase in flood duration could increase the negative outcomes of it generally. On the contrary, Kelman and Spence [3] classified it in terms of hours. Green et al. [118] and Ahmad and Simonovic at [83] address that development of reservoirs could change the duration of flood events tremendously. Some statistics about the effect of dam on flooding say that surprisingly after constructing dam the duration of flood increases [83]. Long duration of flood could also cause habitat losses [118] and more chemical interactions leading to health problems, more cost in clean-up activities [3]. Spitalar et al. [74] worked on specific duration of floods and findings of them are surprisingly that shorter duration of flood events in terms of hours, have caused more fatality events because they occur more. It was suggested that short duration floods should be focused on more than that of long duration.

3.1.4.3 Velocity of Flow

Dang et al. [2] classified it in m/s as addressing that increase in velocity means increase in destructiveness of flood. Increase in the flow velocity could also increase the probability of erosion [2]. Flow velocity and flood depth could dominate the determination of possible negative outcomes in infrastructure, building, health problem because of the chemical reactions and debris during flood events [2], [118]. Green et al. classified velocity into two groups by focusing on mostly damages or collapse of the buildings [3], [118]. He added that dam-break floods could extremely increase the velocity of flow as well [118].

3.2 Factors Affecting Built Environment

Built environment is the area that was affected by humans. They were built for different sort of human activities. Built environment is bounded by buildings, transportation systems and any other sort of structures. It was addresses at [8] that the most effective and sustainable reduction of flood risks can be achieved by decreasing the potential damage so-called vulnerability, which is seen at the border of built environment. All the factors in built environment have some degree of impact on social, economic and environmental welfare. Factors affecting built environment are those can be controlled, rather than estimated. In the following, factors which will be used in the model are to be presented.

3.2.1 Institutional Capacity

It includes such factors as regulations, flood response plan, early warning systems and so on. They are mostly related with the capacity of any institutions that are responsible to flood events.

3.2.1.1 Regulations about Flood

Even though regulations or laws about flood are strict, in practical they are always abused [102], [118], [119]. Without enforcing law there is no need to pass a law as Green et al. address [102], [118]. Especially enforcing regulations in floodplain is crucial [118].

From regulatory perspective, it is necessary to set up some legal barriers toward floodplain settlement as a non-structural measures [89], [128], as well as some constraints about zoning within the catchment [128]. Vari et al. (2003), shows that %80 of the respondents in their research says that in order to encourage people to reduce flood risks, there is a need for authorizes to pass zoning regulations [131]. Existing planning regulations were seen at [122] as one of the drivers of capacity over disastrous extreme events.

Still, the regulations about floods are mainly based on structural parameters which have no sign of sustainability [119]. Even though traditional structural measures are preventative for short term, restoration of floodplains to their natural condition could be more sustainable with regards to flood mitigation. Policies and regulations heavily focus on more structural parameters, which should focus on non-structural measures too [75]. Some applications of environmental protection regulations should also be implied as a non-structural approach [128]. Regulations should include flood risks even though most of the time; it is about urban planning [102]. Land use regulations should not be ignored, as there is a relation between floods with soil characteristics [102]. Regulations related to land use planning should also consider flood risks and local authorities [73]. As building codes play a crucial role in decreasing physical vulnerability of houses and infrastructures [73], [78], [102], [118], they should include flood resilient housing and infrastructure, in terms of building materials, structural features of the construction, occupancies or use of structures [73], [102]. Kadıoglu (2008) addresses that regulations should be prepared related to early warning with regards to source, danger, place, magnitude, probability and action plans [119]. On the other hand, regulations could also decrease the negative impacts of climate change on water pollution [75].

3.2.1.2 Flood Response Plan

It is usual for governments to provide some compensation to victims of flood disaster, and they should encourage people to have insurance [118] or to participate in preparedness stage by themselves [128] for such events. However, there should be something more than helping victims or encouraging them afterwards, especially for people living with flood [118]. There is a need for adequate equipment maintenance and continuous personal awareness in order to decrease such risks and to be ready when disastrous event occurs [119]. The response activities that have led to successful rescue of people should also be included in decision making context [6]. Response plans should be differing between types of floods [89], as the plan is not the same for different type of floods. When the flood loss estimation is held there are some effects of governments, the number of offices and employees [125]. Technical staff in the local municipality or national water courses could impact on flood destructiveness [128], [131]. It is very crucial to own vehicles and equipment in order to response to flood emergencies [131]. Developed emergency response to flooding could decrease the flood risks [73].

When flood response plan is concerned, in order to achieve it practically there is a need to have urban planning approach by focusing on flood disaster. In order to decrease the number of people living or working flood prone areas, there should be developed urban and land-use planning [75], [118] from the light of meteorological and geographic circumstances [119]. While urban land use planning is applied, a hundred year return period of floods should be considered [118], [119]. Land-use planning in the catchment areas should include environmental concerns, protection of natural and cultural values as well [118], [128]. As main purpose of land-use planning, in terms of flood disaster is to reduce the upstream surface runoffs, it can be applied by limiting surface sealing [102], preserving forest cover [102], preserving wetlands and promoting affirmative agricultural practices [2], [75], [102]. Some of the other implementations are multipurpose use of polders, basins or reservoirs, building bypass channels, embankments or mobile flood walls and widening streams and channels [102]. According to mathematical model by Dutta et al., urban land use ratio, floor area fraction and practical use of lands can change economic risks when flood occurs [125]. The value of the structure of land can say something about potential economic risks of flood [118], [125]. Future changes in land use could change the areas' vulnerability as well. So when urban planning is developed there is a need of consideration of possible developments at the future [2], [101].

In engineering respects, such governmental preparations include river management, building flood embankments, controlling engineering standards over flooding, constructing flood relief channels, constructing flood control dams, preventing flood water to enter flood prone areas, controlling floodplain developments, construction adequate reservoirs, building storage basins, and so on [132]. However, such constructions could increase the vulnerability to flooding in reverse in terms of imperviousness [118] or if levees are broken during heavy precipitation events for instance; they could increase the negative impacts of it rapidly [75].

In decision-making respect, there are different sort of governmental preparations [70]. For some countries, it is seen as balancing between stakeholders' actions such as developers, municipalities, residents, planning authorities [128], for others, it is seen as national solidarity [118]. Forecasting and monitoring processes, formulating laws related to risks [75] can be regarded as decision-making approaches for governments. Inundation planning is the core of such preparations and integration between authorities must be held [123]. There should be some meteorology engineer groups working for decreasing the risks of flooding [119]. Economic problems are other issues over mitigation process [75] but it is widely accepted that decreasing the risks of disasters could compensate their possible negative impacts.

Apart from flood response plan, there is also a need of focusing on flood risk management plans. In this term, there are needs for having long-term planning [70], [119], [125] and determination of ingredients of it. It should include possible actions rather than only theoretical approach, making some changes in society and environment, as Plate addresses [101]. However, Green et al. discusses that emergency planning is about co-operation rather than a schedule of actions [118].

In flood management planning, as an example, planning of flood plain areas should be considered [128]. In order to have plan in flood prone areas ESTDAM was developed, for instance, at the Middlesex Polytechnic for the U.K. [125]. In general flood risk analysis, disaster mitigation and preparedness process as some parts of risk assessment should be considered [101], [102]. From another perspective, benefit cost analysis could be used for mitigation processes [125]. Participatory in planning process is also another vital part of planning which should include some actions from households to a national government [102]. In other words, there is a need for understanding local people and behave on behalf of them [128]. They do not want to wait the authorities when flood occurs, they want to have action and planning process must include this problematic [118]. Public participation in flood management plays a critical role in helping to integrate economic, social and environmental objectives [128]. Water resource planning and the management of reservoirs should also be integrated with general flood management planning and strategies [83]. Water resources and the regional properties should first be determined, and then the planning process can be worked, as Ozcan E. addresses [116].

One of the main issues in terms of flooding is creating residential areas within stream beds [119]. Any sort of structure or any people can directly be affected by flood if they are living within stream beds [4], [81]. Because of debris or sedimentation which narrows stream beds after flash rains, it becomes easier for such places to be flooded. So, cleaning up such debris from stream bed in time is crucial in terms of its management [119]. It is obvious that having control over stream beds, no matter the number of people living within them, it is easier to manage with such disastrous events as fragile points of district is known and considered.

As working on separately on such issues does not create sustainable development, in order to decrease flood risks from the root of the problem, there is a need for unification between construction plan and maps [119]. In other words, construction plan should be created from the light of flood danger maps [78], [118], [119] or land-cover maps [75]. There is a need for unifying urban planning with economic vulnerability maps in order to decrease economic vulnerability as well [125].

3.2.1.3 Flood Control Mechanisms

Flood control measures include both structural and non-structural controlling mechanisms [73]. From the structural point of view, in order to control flood, there can be built flood control barriers [4] embankments [119], [125], flood control dams [118],

[2] developed drainage systems [102] upstream reservoirs and dikes [2], polders [80], building retention basins in floodplain inside the town [128]. Source control drainage systems can cut peak discharges too [102]. However, by contrast, failure of such control mechanisms could create devastating flood disasters as well [116], [132]. Because it is not clear whether creating dams could decrease or increase the risks [75], some talks about complete removal of dams has been held in some countries [101].

Flash floods can be avoided by some extent and adequate maintenance of flood control reservoirs [2]. However, all these control mechanisms can be sustainable only if all stakeholders participate in, especially public [73]. Besides, it is easier now to convert forecasting or mappings into mathematical models which could help us to develop more sustainable flood control mechanisms. For instance, series of barrages could be operated by remote controlling when an area filled water with its maximum limits [101]. Erosion and deforestation should be controlled for decreasing risk as one of the control mechanism [123]. As reservoirs are the “quick exit” of flood water, it is necessary to have control mechanism over them [83]. The determination of the impacts of floods on reservoirs is vital to predict future risks [83]. Without adequate maintenance, on the other hand, there is no sustainability of such developments. From another perspective, pollution control systems could also be embedded in to control flows in such mechanisms [102].

Water holding capacity or especially strength of dams, in deeply, could change the areas durability to flooding. There is a need for determination of water discharge capacity, as well as water holding capacity of dams. The controlling mechanism of dams should be embedded for decreasing risks [123]. Wastes in a dam could also decrease the predicted maximum capacity of dams and could create unpredictable events or overflows [123]. Experiments show that building dams could impact inversely as well, by increasing runoffs near the region [133]. Integrating early warning systems on such structures could help to control its limits [134]. In order to decrease flood risks, dams could be operated dynamically to provide maximum flood water retention capacity via remote control too [89].

In terms of maintenance of such mechanisms, as sedimentation and blockage are some of the issues increasing runoffs, periodic maintenance of stream beds, banks and infrastructure facilities or periodic cleaning of them could increase the discharge capacity of hydrological networks [79]. It can be said that, in some part of the world, one of the precursor factors increasing flood risk is seen as insufficient maintenance and improvement of levees [131].

3.2.1.4 Flood Risk Hazard and Social Vulnerability Maps Risk

Different sort of maps have been generated in order to decrease flood risks. ‘Which area can be flooded by how much rain’ maps are generally called as flood hazard maps [119], and it is known generally as inundation simulations [125]. Such maps are created for risk deduction especially for flood plain areas [70] and identify weak points of a district to flood events [101]. Besides, risk maps help its users to compare the elements of risk in quantity [102]. They are generated mostly by using GIS software based on vulnerability and topographic maps [101]. Without implementing the characteristics of population into the map, they would not work adequately [118]. Erosion, floodplain or snow slide basins should also be determined first and their risks should be mapped in order to decrease risk and give public alerts before the events in timely manner [119]. Meteorological observation is the hearth of such maps because they could give some information about the way of rainy clouds or air ventilation [119]. Public participation is necessary for creating or developing such maps [119]. Land use mapping is another type of mapping that should be integrated with others [70], [125]. From the light of above, it can be said that the capacity of such maps in institutions that could generate a huge amount of data enabling individual to be responsible to take precautions, could alter the areas flood endurance. Correlation with risk plans of them could also make it easier to control flood events.

For instance, Scheuer et al. (2011) examined high income household percentage, unemployment, number of hospital beds, youths, food stores, number of doctors, stops of public transportation and then mapped social and economic capacity of an area related to flood risk [80]. Besides, Thouret et al. (2014) used GIS to embed vulnerability and hazard maps to measure susceptibility of buildings [135].

Risk maps, in general, are combination of hazard maps and vulnerability maps [73], which enable us to identify most endangered places [102] and individuals [78]. Vulnerability maps enable us to understand social, economic and environmental conditions of areas, helping to create unified risk maps in order to decrease risks [78]. Without such vulnerability maps, it is not worthwhile to create risk maps only in consideration with structural and hydrological elements [118]. Such socio-economic characteristics are mainly; income level, tenure type, insurance, average age and household types [78].

3.2.1.5 Capacity of Meteorological Observation Stations

Causes of flood events are mainly depend on meteorological and hydrological parameters and therefore it is necessary to integrate atmospheric, climatic and hydrologic parameters in order to have data about whole flooding process in more developed way. It should include from soil moisture level to snow cover level, from storm probability to quantity of possible rainfall in order to estimate the potential event appropriately [123]. As it is the subject of flood forecasting, increase in the capacity of them could inevitably increase the forecasting process and its preciseness [73].

Determination of 'How much rain could lead to how much destructive flooding in which places' could be another development which can reduce flood risks [119]. Such developments could help people especially for those living in flood prone areas [118]. As dissemination takes time, and forecast reliability is another problematic, there should be more consideration over warning lead time and reliability of it [118]. There are some focuses over such issues but the main concern is gathering all different sort of data and giving it as an advice to the last so-called consumer [118], even though there is no enough resolution of physical characteristic of the flooded area in current meteorological search networks [125]. However, it is obvious that forecasting short duration and heavy flood events are more challenging [74]. If the event is not accurately forecasted early enough, then it cannot be called as an effective forecasting [6]. Without converting it into practice it does not mean anything to gather huge amounts of data [102]. For effective forecasting from meteorological networks, there is a need for considering future changes on urban floods, because of land-use change, climate change and so on [102]. By integration between such networks with social factors [78], there will be more accurate vulnerability forecasting.

3.2.1.6 Early Warning Systems

Early warning time and the determination of possible flood events, especially flash floods, can inevitably reduce the negative consequences of it [123], as it makes community more resilient to rapid changes in environment [75]. Flood warning systems are designed to increase effective response of individuals over flooding [132]. As a non-structural parameter, when time of warning decreases, it gives operators some time to increase defensive operations over flooding [70]. In order to increase time for preparation there is a need for decrease the time of dissemination too [118]. Delivery time of the warning information and emergency alert depend on directly complete communication systems [136]. So, flood warning systems should include the dissemination of the information to people [73].

Early warning system developments include all type of warning procedures. Developments could make community more resilient to rapid changes in environment [75]. It does not include only flood warning, it also includes, for instance, reservoir spillway warning system as warning to operator when reservoirs reach their maximum level [83] as well as river water level warning, overflow warning, extreme weather warning and so on [119]. Adopting sensor based system to early warning system could also be effective, especially for flood prone areas [101]. In general flood warning system management presents risks and it includes probability and consequence by their importance and these risks could be examined more. Multiplying probability and consequences degree will not give correct result every time [70]. There is a less time to take place emergency procedures in flash floods with short duration so there is a need for developments for such short duration events even though it is very challenging to improve it in hydro-meteorological perspective [74].

Flash floods could occur very rapid sometimes and therefore in some cases there might be number of deaths before warning [4]. The main purpose of developments should be for loss deduction and warning can be effective only if the public participation is embedded [6]. Compliance is another key indicator for effective management of such systems [4]. Decreasing the number of false or non-suitable warning is also another key indicator [101].

3.2.2 Urban Infrastructure

It includes such factors as water supply and sanitation capacity, transportation network capacity, telecommunication capacity, electricity generation and distribution system capacity, natural gas distribution system capacity. For these factors, they are both element at risk and ones leading to vulnerability for people and their properties.

3.2.2.1 Water Supply and Sanitation Infrastructure Capacity

Drainage of flood water, without doubt, is one of the most important factors for especially urban flooding as water that is not infiltrated pass to these drainage channels. In urban areas, drainage systems are designed to get rid of runoff water as quickly as possible by discharging this water to the nearest water courses [118]. As in urban areas imperviousness is high and heavy precipitation cannot infiltrate into the soil purely, runoff water is needed to be drained [102]. When drainage systems cannot compensate the water flowing, a flood event occurs. Without adequate drainage systems and its maintenance, some small scale floods could also harm enormously [102]. Without adequate frequency in maintenance of such systems, rubbish and debris could block the drainage systems [79], [131]. Moreover, if a drainage system is too efficient in upstream areas, it may results in downstream floods [102]. The reason for the increase in the frequency of flash flood is ageing infrastructures which have become under-designed [132]. Cities in coastal areas are more in danger if there is no pumping in drainage. Without pumping, for such places drainage is very difficult [73].

For instance, insufficient drainage channels are in common in Bangladesh, which makes it one of the most flood vulnerable countries over the world [5]. To decrease the duration of flood, which is one of the characteristics of flood, improvement in drainage capacity is necessary [2]. The main reason that water drainage systems could create flood vulnerability is that runoff water exceed system capacity [137]. Even though there are adequate infrastructures, if there is a problem about efficient maintenance of it, it will increase the flood risk as well [102], [128].

In order to have flood loss estimation, drainage systems' behavior under different flood events should be examined. Data related to pipe blockages should also be gathered to have flood estimations [137].

Even though in most of the places, rainwater sewage systems are separated, in some places they are combined. In heavy flood event, exceeding the drainage capacity of systems, contaminated water could emerge as a runoff, resulting in contamination problem.

Water treatment, storage and supply pipes are element at risk as well [118], [125]. Damage to drainage or irrigation system can be very severe too [2], as well as damage to sewage systems [125]. It was emphasized that storm drains and sewers could be element at risk if they were designed under its normal limits [132].

3.2.2.2 Transportation Network Capacity

It includes the vulnerability of vehicles, road systems, rail systems, waterway systems and even airports or underground rail systems. In general transportation systems are highly vulnerable to flooding [132]. Urban road systems can be easily interrupted by flood waters [132]. If they were damaged, travel disruption or traffic congestion could occur directly [136]. So, such systems should be regarded as one part of economic vulnerability. Transportation in general can be regarded as element at risk in flood events [125], [135], [136]. Vulnerability of road traffic and underground rail systems should be analyzed [132]. As roads are at the accessibility part of the other parameters, it is crucial for them not to be interrupted [80].

Roads are in crucial position, as they always touch flood waters; when flooding become severe, it is inevitable for roads to be damaged [5], [138]. As transportation systems are indispensible for people in any time, being decreased of their vulnerability is crucial. In addition, damaged roads could increase the time that people go from anywhere to hospitals, if they are hurt by flood event [138]. Especially if the roads are in floodways potential damage to them from flood water becomes more destructive [2]. Road closures could also impact on fatality and especially injury rate [74]. Interruption of traffic could be regarded as an indirect damage of flood events [2]. Transportation interruption includes, delay cost per unit time as well as traffic volume too [125].

As roads could be seen as some pathways of water, by increasing infrastructure level of them, creating adequate pathways for water on them, the vulnerability could decrease [119], thus flood risks. From another perspective, road networks could be regarded as embankment in some areas resulting in preventing the floodwater movements from rivers [125]. If roads or transportation density increase in general so do increase in flood risk [2].

3.2.2.3 Telecommunication Capacity

This factor covers all type of communication and information services that is distributed. As by flood events they could be damaged too, this factor reflects the economic vulnerability of such telecommunication installations [118], [125], [132].

Loss or disruption of communication is seen at [102] as one of the flood losses. Telecommunication facilities and systems are one of the critical lifelines [135]. Vulnerability of an area is also based on communication capacities of the places [136]. For instance, Parker (1995) addresses that some cables are more susceptible to flooding than others and they should be embedded [132]. This factor is also both in element at risk and the parameter affecting vulnerability of people.

3.2.2.4 Electricity Generation and Distribution Systems

As Electricity generation and distribution systems are one part of urbanization and are also element at risk [2], [125], when an area flooded, as they could be damaged, unexpected maintenance could be needed as outages can occur [118]. As supply of electricity could be interrupted by floodwater, especially if sub electricity stations are near to flood prone areas, they are in economic vulnerable part of flood disaster [132]. As electricity is one of the utility supplies, it is one of the factors related to economic flood loss [102]. Flooding can also cut electricity damaging to some susceptible devices as well [2], [102]. Power generating systems are seen as one of the critical lifelines at [135]. To sum up, power generating systems are also both at element at risk and the ones resulting in vulnerability for people.

3.2.2.5 Natural Gas Distribution and Storage Systems

As natural gas transmission and storage capacities are important for public and maintenance of them is costly, they need to be addressed in terms of flood vulnerability factor. Physical damage to such facilities could lead to outages beyond the flooded areas [118]. They can be regarded as element at risk as well [125].

3.2.3 Land Use

It includes such factors as residential building rate, commercial building rate, industrial building rate, agricultural usage rate, historical and archeological site rate and special public use building rates. For these factors increase in them could result in imperviousness as well as economic vulnerability. For some of them, low occurrence rate of them could also result in vulnerability to people such as special public use buildings as it covers hospitals and schools.

3.2.3.1 Residential Building Rate

Residential buildings are, without doubt, one of the elements at risk caused by flood. In most of the cases, economic damages occur in residential areas because of unplanned urbanization [116]. Damage could be shifted if residential housing rate is high in flood prone areas. As well as physical damages to buildings, evacuation costs and heating cost is affected by flood [118]. Flood damages to urban areas can be classified into two categories which are damages to residential and non-residential buildings [118], [125]. In residential buildings; type of structures, total floor area, value of any structure per unit, height of building, household distribution are sub-parameters, while they are not considered in non-residential building.

It is obvious that in residential and commercial areas perviousness is low, resulting in more overflows [75]. Residential settlements especially along with the river valley are blamed for increasing flood risks too [75]. Such settlements will inevitably reduce flood drainage capacity of an area [73].

From another perspective, in residential areas, flood water is contaminated more because of the probability of flooding of sewage systems [118]. Dang et al. address that increase in residential housing rate will also increase the economic vulnerability [2]. The reason of such increase is that people and their properties can directly be affected by flood events [2]. Damage to residential buildings can be categorized as property and structure damage, content (stock) damage and, emergency and clean-up costs [125].

3.2.3.2 Commercial Building Rate

Commercial buildings include retail buildings, office buildings and so on. As the impact of commercial buildings on the economy of a district is obvious, there is an economic vulnerability of them. Business interruption was shown at [125] as one of the primary flood damage category even though it is intangible. It was addressed at [75] in a case study that agricultural and commercial lands nearby the Lake were one of the mostly affected areas by flood. Commercial areas located in low-lying areas more in danger than others [116]. Flood could also disrupt trade and decrease income from tourists as they could choose flood-free areas alternatively [118]. It was addressed at [81] that flood damage to commercial sector far exceeds to that of residential sector. In addition, content loss of commercial buildings is also one part of economic vulnerability of such places [125], [81].

3.2.3.3 Industrial Building Rate

Industrial buildings mainly include buildings used for manufacturing and repairing. In industry where the production rate is important, the production quantity or quality can decrease due to flood interactions [118]. Manufacturing disruption, loss of sales and exports could be regarded as economic aspects of flooding to industries [118]. Because of urbanization, industrial areas are becoming in elements at risk [123]. Highly industrial areas could also decrease the capacity of drainage systems [73].

There are some industries with high risk such as nuclear, aeronautic and chemical industries, in which methods to quantify its risks have been developed [137]. Industries emitting wastes or chemicals can contaminate flood water if it touches, which could impact on people in health terms, and their properties [2].

3.2.3.4 Agricultural Usage Rate

As in rural areas, agricultural usage of the land is higher, and agricultural usage is important for the public in economic terms, when flood event occurs in such places, public is affected seriously as an economic opportunity loss [5], [73]. So there is a need to control agricultural activities in order to decrease flood risks [79].

It was addressed that agricultural lands nearby the Lake were one of the mostly affected areas by flood in the case of typhoon Rusa for instance [75]. Especially for agricultural areas which are placed at low altitude [116]. In areas where agricultural usage is high, there are some different damage categories some of which are; damage to crops, damage to farm houses, damage to farmlands and infrastructures [125].

Agricultural usage was divided into five categories by Dang et al., which are riversides, grassland, paddy field, vegetable and orchard. It was addressed that orchard takes the highest weight in flood vulnerability because of their high economic return. Nevertheless, agriculture in general, takes the least weight in economic term compared to infrastructure, public use buildings and residential buildings [2].

In terms of agricultural use, losses because of floods are most of the time less important than losses because of inadequate drainage. The problem in lands used for agricultural benefit is land drainage rather than flood reduction. Thus controlling soil water level is an important agricultural measure for people having land with agricultural use [118]. In some cases, however, flood provides benefits by replenishing the fertility of soil [118].

3.2.3.5 Public Infrastructure Rate

It is obvious that increase in public infrastructure such as bridges, dams, transportation networks, airports will undoubtedly increase the economic vulnerability of them as a result of heavy flood events, especially if they are located in flood prone areas [102].

Infrastructure parameter is, generally seen as the affected type of parameter rather than effective [74]. Because of that, they could be regarded as one of the vulnerability parameters. From economic point of view, as infrastructures have high economic value, because of some flood interactions [73], erosions or storm surge, deterioration of them will be negative consequence of flooding [102]. Susceptibility of infrastructures, as well as people, should also be determined [135].

However, because of high uncertainty during flooding, it is hard to measure the effect of specific floods on infrastructures [125]. It is obvious that increase in the public infrastructure in m/hec will increase the economic vulnerability of flooding [2].

Building codes play an important role to decrease vulnerability of infrastructure as well [73]. Vulnerability of infrastructures needs to be worked as they play an important role for quality of life [80]. Repairing public infrastructure is also one of the important actions that should be considered.

3.2.3.6 Historical and Archeological Sites

Historic buildings, the places with spiritual value, heritage areas or archeological sites can be element at risk in some cases. For instance, historic buildings in urban sites where they are nearby the river or flood prone areas become one of the flood vulnerable sites. In such cases flood proofing might be appropriate solution to protect such places [118]. Dang and Babel (2016) addressed that spiritual value such as temples, pagodas, churches, museums or any sort of cultural characteristic are one of the component of social vulnerability [2]. As surroundings of rivers are often described in terms of their heritage values, it is hard to implement flood control measures which threaten such spiritual values [128].

3.2.3.7 Special Public Use Building Rate

It includes such places as hospitals, schools, medical services, pensioners' homes, fire stations and so on. They can be named as social infrastructures [80]. Physical damage to such places results in disruption of public services [2], [80], [118], [132]. Special public use buildings such as schools, hospital, markets and administrative buildings is one of the main components in economic vulnerability addressed at [2]. They are very fragile and crucial for public in any case for social welfare, which increases the vulnerability of them. However, as they are important facilities for social welfare, increase in the number of them will decrease the vulnerability of people in the related district. If the number of them is high, it can be said that the area is with low risk but high coping capacity [80]. These places could be regarded as strategic elements in crisis cases [135]

3.2.3.8 Structuring Rate in Flood Danger Zone

It is obvious that increase in the number of people living in flood prone areas could increase the number of building or any sort of structures in such areas so do increase in vulnerability of such structures. It is obvious that the zone of a building that is constructed could change the vulnerability level of a building, from economic perspective [119]. This factor is regarded over the main factor named “superstructure capacity.”

3.2.4 Superstructure Capacity

It includes such factors as structural type, durability, age of building, floor area coefficient, existence of basement, rate of buildings with insurance, rate of building without permission from municipality and floor covering

3.2.4.1 Structural type

The material used for the buildings structure could also change the vulnerability of building. Building codes for different flood zones could be embedded in structural context [118]. In terms of construction material, Thouret et al. (2014) address 5 type of construction material which are; wood, handmade porous brick, industrial less porous brick, ignimbrite, concrete or cement, by giving their vulnerability as 100, 75, 50, 25, 0 respectively [135]. Dutta et al. (2003), however, divided construction materials into concrete and wooden [125]

3.2.4.2 Durability of building

The term flood risk also includes the damage of flood to buildings and collapse of buildings in terms of economic losses [2], [3], [101] [102]. Dutta et al. at [125] divided flood loss to the building into four categories, which are: damage to building structure/property, damage to building contents/stock, damage to outside property, emergency and clean-up costs. While the area flooded in 1997, the number of flooded buildings was 3.2 times larger in comparisons with 1934 flooding [118]. Structural type of buildings, the usage of them, engineering assessment of them and the area they are constructed in whether they are in floodplain areas or not [119], could alter their vulnerability to flooding [118]. It becomes necessary to use adequate building codes and considering national housing vacancy rates [78], in terms of flood as well as other type of disasters. Jonkman et al. at [4] examined 13 flood events and found that 6.1% of all deaths were in the buildings. There is a term in flood disaster as ‘at home vulnerability’ [6].

On the other hand, in fortification phase of flood recovery, there should be followed ‘building back better’ principle. In order to achieve sustainable development, there should be some principle building codes for fortification [102]. The durability of buildings encompasses all these properties.

3.2.4.3 Age of building

It is obvious that the age of a building could change the vulnerability of it. In general as old buildings are more susceptible to flooding, increase in average age of the buildings could increase the vulnerability. In the study at [135] age of building is determined as one of the building characteristics in terms of flood resistance. In terms of infrastructures, the age of the drainage systems are also one of the causes of system blockages [137].

3.2.4.4 Floor area coefficient

As increase in the floor area coefficient could increase the concrete layer thus decreasing imperviousness in more small scale, buildings with high floor area could become more vulnerable. Residential and non-residential buildings’ floor area where estimated in the study of Dutta et al. (2003) in order to calculate the unit value of any properties [125].

3.2.4.5 Existence of basement housing

For the buildings with connected sewage and storm water drainage systems, after heavy rainfalls, sewage flooding could occur over the basements of the buildings. When the maintenance frequency of drainage facilities is low, it is inevitable that pumping of water will decrease, resulting in basement flooding [132]. Flooding of basements are mainly occurs as a result of high groundwater tables in some places [137].

3.2.4.6 Rate of buildings with insurance

Insurance is one of the non-structural parameters decreasing flood vulnerability in economic terms after flooding occurs [6], [119], [125], [128], and the main purpose of insurance is to distribute risks [102], [118].

Economic vulnerability appears with people who cannot afford insurance purchases, in other words, people actually most in need [70], [102]. The insurance could involve health of people or their properties as well [78].

Insurance policies could change country by country depending on whether there is a duty of government for providing disaster relief or not. So there is a need of cooperation between insurance agencies and governments [118]. Flood insurance can be extended for farmlands, especially for orchards, from agricultural view [2].

In order to obtain more feasible solution, creating insurance pool could be a good approach to manage with such flood risks [131]. Smith addresses that commercial or business interruption losses were overestimated. As there are some losses to retail outlets because of flood, meanwhile there will be some benefits of it to flood free outlets. It means there is no economic loss in overall [81].

Moreover, Smith (1994) addresses that stage damage curves were first used for national flood insurance act in 1968 in the USA, administered by Federal Insurance Agency [81]. It was used in providing financial helps for buildings located in flood prone areas in which houses were divided into insurance classes all of which has their stage damage curves depending on structural type of the buildings. After all, stage damage information includes electrical wiring, gas and water, gates and fences as well as building structures, and then it includes furniture, fittings and household appliances [81]

3.2.4.7 Rate of building without permission from municipality

It is obvious that buildings which have been built in high risk areas without a permit are more in danger than others which have a permit. In order to achieve adequate flood management strategies, some says that governments should compensate only victims living in a building with a permit, as an insurance strategy [131].

3.2.4.8 Floor covering type

As the covering material of building or any floor can directly impact the negative pressure of flood water in terms of water insulation capacity, there will be some impact of economic loss. The material used in coverings can change the durability of building over flooding [81]. Chemical actions could also erode such materials as brickwork, glass, timber, or PVC [3].

As coverings with asphalt and concrete could decrease the absorption of water, the water insulation of coverings should increase to decline the risks of flood [128]. It was mentioned at [102] that for instance parking surfaces should be made of more permeable materials so that surface runoff decrease.

3.2.4.9 Fortification to the Flooded Buildings

Flood event could affect some properties of buildings. It could be mostly to be damaged, collapsed or flooded. Fortification to such buildings as a reconstruction action could decrease future flood risks [101], [119]. In fortification phase of flood recovery, there should be followed ‘building back better’ principle [102]. In order to achieve sustainable development, there should be some principle building codes for fortification of flooded buildings [102].

3.2.5 Demographic and Social

It includes such factors as income level, population density, disability and health condition, level of education and awareness of people. It indicates sociocultural and demographic attributes of the people in affected areas.

3.2.5.1 Income Level

As income is a parameter that represents ability to pay for some necessities and services, related to disaster preparedness, increase in income level of people could increase better conditions in accommodation, having car, better clothing and so on, which can decrease the vulnerability of people [2]. Higher economic income could let people to save some money for emergency operations as well [78]. Poverty directly affects the capacity of people to protect themselves or their property in any respect [2], [102]. Housing without any hygiene standards are also one of the risks of flooding [102]. People with low-income could live without any insurance to flood events, or more likely to live in flood plains, which make them more vulnerable as well [118].

3.2.5.2 Population Density

As urban or rural areas can change by population density and the threat of flooding can change by the type area, population density become more necessary to examine in terms of flood impacts [2], [83], [102]. Calianno M. et al. shows that in terms of flash flood injuries or fatalities as a function of density, rural areas are more exposed than urban ones [74]. Even though the possible damages of flooding is higher in rural areas, if it occurs in urban areas it could hurt more people as more people are living there [74], [118]. As the density is high in urban areas, public participation could play a crucial role in decreasing flood vulnerability [128]. Increase in population could inevitably force people to move polders as well as increasing the number of people living in flood plains [75], [101]. When the density of population increase, so do land use change, resulting in vulnerability as the number of building inevitably increases [2], [123]. In terms of social vulnerability to flooding, population is the heading parameter [2]. Increase in population could also increase the possibility of water disease outbreak too [2]. In order to decrease risks related to this issue, there should be developments in residential usage capacities of risky areas [119].

3.2.5.3 People in Need and Health Level

It is obvious that healthy people can resist physical stress more than those with lower health conditions, thus increase in health level inevitably decreases flood vulnerability [102]. Physical or mental health histories of people, current physical or mental health level of them, capacity of self-reliance of them could also change their vulnerability level to disasters [4], [118]. Physical and psychological health of population is one of the most crucial social indicators of flood disaster [2]. There are some associations between flood risk and income level therefore less income level lead to housing without health or hygiene standards, increasing the negative outcomes of flooding [102].

Apart from that, vulnerability of a person scale can change by disability as well [78], [118]. Actually it is not a parameter itself, however, when it combines with, living alone, being old or not having a car, flood vulnerability could increase and the suitability of actions taken by a vulnerable one can change when flood occurs [78]. People, who have sensory disabilities, having speech, hearing or vision problems, are at greater risk because they cannot receive information related to disastrous events properly. Disability as a parameter is one of the hardest parameters to measure [78].

Apart from that, being very old or a baby can increase the individual vulnerability. Elderly or very young people can be regarded as more vulnerable at [4]. Dwyer et al. suggest that, people aged over 65 and fewer than 5 are more vulnerable [78]. Some hearth attack events can be seen in some flood events for mostly elderly people [4]. However, vulnerability of elderly people cannot be associated only with age; actually it is created by integration of living alone, having no car or having a disability [78].

3.2.5.4 Level of Education

As education level covers all types of education and could change directly of public perception, it could be regarded as one of the social parameters [136].

Education could change behavior of people from negative and risky to positive and safe, making them less vulnerable to flood disastrousness [78], [119]. Lack of access to education makes people more vulnerable in some parts of the world [118]. Apart from that, as increase in education can increase public participation in preparedness, response and rehabilitation phase of disasters, level of education become more and more important factor related to loss level of flood. Public participation should be implemented especially in urban areas where there is shifting population [128]. As a result, level of education in an area can change the risk of residents over flooding.

3.2.5.5 Public Awareness

In terms of flood awareness, it should include education of evacuation and 'what to do' actions [119]. Awareness and education of flood rescue personnel could also help to bear flood events [119]. According to risk perception of people, changing behavior of them is necessary to be understood and examined [70], [78], [79], [128]. It could give us some insights about 'what is more important for people' and 'what can change their behaviors' when flood occurs [78]. People mostly behave according to their perception, education, emotional capacity and experiences [78]. One third of flood related fatalities are not about drowning, for instance. Vehicle related drowning could occurs very frequently especially at the onset of flood when people first surprised [4]. Some programs should be embedded by public about flood education and awareness, in order to decrease such risks [4], [128]. As dams are wasted by public decreasing their water holding capacities, public should be educated over such issues as contamination as well [123].

3.2.5.6 Population Age

As age of a person can change their capacity to cope with devastating and sudden events by changing their behavior, it can be regarded as one of the flood parameters [4], [6]. Most of the flood events hit elderly people when they are at their home, while hit young people when they are at outside [21]. For instance, 55 per cent of people who died in flash flood events in the U.K. are under the age of 21 [4].

3.2.5.7 Flood Experience

People with flood culture, or experienced flood frequently can do pre-event adaptations and behave more decently for event responses than those have not experienced yet [128]. If one has not been affected by flood, but witnessed, it could also be regarded as a person experienced flood [128]. It could improve flood perception of people [2], [118].

3.2.5.8 Swimming Ability

As people may need to swim in order to pass flood water when it exceed maximum walking depth, having such swimming abilities could help people to rescue themselves and to help their neighbors [4].

3.2.5.9 Public Participation

One of the key issues of flood disaster management is inclusion of public to participate in such processes [118], [128]. Public participation should be implemented especially in urban areas where there is shifting population [128]. It is also necessary to understand public perception to flooding which could increase public participation [118], [128]. Institutional participation can also be integrated with public so as to have maximum control over flooding, in terms of decision making process [102]. Public participation over development of hazard maps could also decrease such risky circumstances [119].

3.2.5.10 Tenure Type and Rate

Tenure type is one of the second order socio-economic vulnerability indicators, in terms of post disaster relief, because if people have their own home, they could be rehabilitated faster than those who have not own a house [78].

3.2.5.11 Gender

According to findings by Jonkman et al., males are overrepresented in car crashes, drowning and physical injuries [4]. One possible reason for higher vulnerability of males is that they have more risk-taking behaviors than females [4]. However, Dwyer et al. suggest that females are more vulnerable than males in the context of flood [78].

3.2.5.12 Use of Alcohol

Some findings suggest that there is some fatality events occurred due to high alcohol level, presumably because of drunk-driving actions [4]. It can be said that those who are drunk during flood is more in danger than those who are not.

3.2.5.13 Household Type

As changes in the population of a single house, could change the behavior of the households, it could be seen as one of the flood parameters [125]. There are several household types which are; couple alone, couple with dependent children, single parent with dependent children, group housing and living alone. In disastrous situation, most immediate support network can be created in extended families. Those living alone could be seen as the most vulnerable ones as they may not get help immediately if they are injured [78].

3.2.5.14 Car Ownership

As transportation is an important necessity in mitigation and recovery process, having a car could decrease sufferers' vulnerability [78]. However, from economic point of view, cars are another element that could be exposed to flooding thus being susceptible to flood damage [78]. From another perspective, as there are a huge proportion of car-related fatalities, increase in car ownership proportion could also increase the risky situations.

3.2.5.15 English Language Skill

Flood may happen anywhere, those who are tourist in foreign country, if they experience flood, English language skill help them to acquire information and to communicate specialist to protect themselves.

3.2.5.16 Debt and Saving

From the economic vulnerability perspective, it can be said that, people who have savings are less vulnerable and who have debts are more vulnerable in terms of recovery [78]. The savings can be used as household emergency money as well [78]. Obviously, the rate of income over expenditure could decrease the vulnerability of a sufferer.

3.2.5.17 Employment Rate

It is obvious that increase in the rate of employment will inevitably vulnerability of community within a district over flood disaster. High income household rate and unemployment were used at [80] as economic coping ability indicators to flooding.

3.2.6 Ecological

It includes such factors as water pollution, soil pollution, flora and fauna associated risks.

3.2.6.1 Water Pollution Risk

When flood occurs, people living near the sewage treatment systems, waste dumps or places that emit harmful chemical waste are more vulnerable than others, in health term [102], [118]. By considering long term risks; soil, superficial or ground water can be contaminated by polluted flood water [2], [102], [118]. Contamination of water could carry some dangerous diseases which creates health risk for people [2], [123]. Especially if flood water is contaminated by industrial wastes, it could pose huge health risks [2]. Chemical reactions caused by contamination could also be regarded as flood effects on people or their properties [3], [4]. This chemically contaminated flood water could contaminate fresh water supplies and could also lead to fire [118]. Several ecological or environmental damages can also occur because of the contamination of flood water [2], [118]. Vapor from contaminated flood water could also cause some damages [3]. Contaminant water could also increase the potential risk of nuclear action if nuclear plans are stated within possible flooded areas [3].

3.2.6.2 Soil Pollution and Erosion Risk

In terms of soil pollution, even though flooding may provide benefits by replenishing the fertility of soil [118], [132], they could have some negative impacts on soil if water is contaminated.

In terms of erosion, it could occur as a result of flood events [3]. However, it could be related with flood risk parameters because the same quantity of water will not have the same effect in terms of erosion probability. The slope of the topography, the types of settlement could change the erosion probability and when the condition of such factors and flooding occur at the same time, the risk becomes more considerable [119]. In order to reduce such erosion probabilities, afforestation [118], stabilization of river bank, developed agricultural usages and construction of better reservoirs could be applied [102]. Bed roughness could also change because of erosion [3]. Flood ways, fallow lands and deep slopes are the place with high potential of erosion [2]. Erosions created by floods could cause disturbances to the ground and vegetation, which can cause the failure of infrastructure as well [2]. Soil erosion after flooding could block roads and inhibit immediate post disaster recovery activities [75]. Apart from that, afforestation could decrease the probability of erosion as well [102], [118]. As a result of erosion, discharge capacity of an area becomes more defective [79].

3.2.6.3 Flora Associated Risk

Animals affected by flood water can also be regarded as risks related to flooding as animals are the part of habitat [102]. So, there is a need for creating special teams to care flora associated risks.

3.2.6.4 Fauna Associated Risk

Even though it can be argued that flooding could have positive impacts on ecology in terms of biodiversity especially in rural areas [102], negative impacts of it cannot be ignored [118]. Especially high flow and long duration flood events may cause damages habitat losses [118]. Rivers could be highly polluted because of the sediments containing harmful chemicals carried by flood waters too [118].

Forest areas, with different sort of trees may be sensitive to flood inundation. Moreover some susceptible protected biotopes can be regarded as elements at risk in terms of ecological risks of flooding as they could have low level of durability [80]

3.2.7 Accessibility

It includes such factors as location of the population, accessibility to services and timing of flood event.

3.2.7.1 Location of the Population

Because of the fact that vulnerability of people can change by whether they are suited in floodplains or not, the location of them becomes crucial. It also includes the rate of the population living near the coastal areas and people living the areas with erosion probability.

3.2.7.2 Accessibility to Services

The location of a flooded area, by considering whether people are closed to public services such as hospitals, transportation services and supermarkets, without doubt, is a crucial factor in terms of accessibility of people.

3.2.7.3 Time of Flood

As place of people at flooding moment can alter the capacity of them, the time becomes crucial because they could change the places of people in. For instance at night people are mostly at their home, in the afternoon they are at work, or on evening they are on their way [6]. The time of the flood event can change the response time to the event as well [6]. In terms of time, visibility can change with it [74]. There is no consensus over which time should be examined from beginning to the end of a flooding event [74].

CHAPTER 4

DATA COLLECTION AND ANALYSIS

In this chapter, frequency analysis of all flood risk factors, pilot study so as to check suitability of factors and to divide all factors into controllable and relatively not controllable ones, AHP workshop to weight controllable factors, determination of flood mitigation measures associated with controllable factors, development of agents and agent environment in the context of Multi agent system (MAS) will be illustrated.

4.1 Frequency Analysis

As a result of a comprehensive literature review, frequency analysis was conducted. For 74 factors, 35 researches have been checked if they contain any of the factors. The results of frequency analysis can be seen at Table 4.1.

As it can be seen from the table, weather condition, demographic and social, and land use main factors were mentioned mostly by 110, 109 and 95 times respectively. The reason for weather condition is that flood disaster have direct link to weather conditions. For demographic and social factors, it has been mentioned because there are a huge number of sub factors in it. For land use factor, it is probably the high possibility of the negative consequences of flooding due to the imperviousness of used land However, when the average mentioned quantity is concerned for each main factors, flood characteristic main factor is seen at the head by 21 meantions followed by institutional capacity factor by 14.16, where that of minimum is superstructure capacity factor by 5.375. According to the studied papers, the mostly considered parameters are; flood depth, flood duration, quantity of rainfall, residential building rate, early warning system and population density by 23, 23, 22, 20, 19 and 19 considerations respectively.

By looking at each main factor quantity of rainfall in weather condition; rate of occurance in flood plain in environmental; soil moisture level, basin size and shape, river discharge and, topographic and morphologic conditions in basin characteristic; flood dept and duration of flood in flood characteristic; early warning systems in institutional capacity; water supply and sanitation capacity, and transportation network capacity in urban infrastructure; residential building rate in land use; rate of building with insurance in superstructure capacity; population density in demographic and social; soil pollution and erosion risk in ecologic; time of flood in accessibility were mostly mentioned factors in their inner classes. Therefore, the least considered factors are; floor area coefficient, fauna associated risk, swimming ability, English language skill, use of alcohol, tenure type and rate, by 1 for each of them.

4.2 Process of Data Collection

From the light of frequency analysis, the study is divided into two phase which are pilot study and workshop. To refine the factors and to narrow down them into controllable cluster, pilot study was conducted with 2 faculy members in civil engineering department and 1 local authority employee in managerial level. The final list of factors reduced to 35 controllable factors with 6 main factors which are; institutional capacity, urban infrastructure, land use, superstructure capacity, demographic and social, and ecological. 45 actions were also determined from the literature review. In the same pilot study, interviewers were also asked to check these strategic actions to reduce flood risk based on 35 factors. As a result, 59 strategic actions were also concluded by 3 experts, which can be called as a course of action. They will be used in the next part of the study.

Analytical Hierarchy Process (AHP) matrices were constructed based on 6 main and 35 controllable factors. Secondly, AHP workshop is conducted with the number of 8 experts. In brainstorming session, the experts stated their opinions about flood factors in 1-9 scale of AHP. The answers of 8 experts were calculated in Excel Program by using their experiences exponentially, and geometric means of the answers were consolidated. The results for each pairwise comparison were run in Superdecision program and inconsistencies were checked. If it is acceptable, then the next cluster is checked, otherwise we turn back to the brainstorming session again for the same cluster. As a result, relative weights of each factor were determined. Steps in data collection are shown at Figure 4.1. Grey colored outputs in the figure will be used in MAS process.

Table 4.1 Frequency analysis of the risk factors affecting flood loss level

ID	W1	W2	W3	W4	W5	W6	W7	W8	W9	En1	En2	En3	En4	B1	B2	B3	B4	B5	B6	Fc1	Fc2	Fc3	I1	I2	I3	I4	I5	I6	U1	U2	U3	U4	U5
Sub Factors	Temperature	Air pressure	Wind velocity	Wind direction	Atmospheric moisture	Quantity of rainfall	Duration of rainfall	Type of Precipitation or event	Frequency in flood occurence	Impervious area percentage	Woodland and vegetation rate	Coastal area rate	Rate of occupancy in flood plain	Soil moisture Level	Groundwater level	Basin size and shape	River discharge	Topographic and morphologic conditions	Entrance and exit geometry	Flood dept	Duration of flood	Velocity of flow	Regulations about flood	Flood response plan	Flood control mechanisms	Flood risk hazard and social vulnerability maps	Capacity of meteorological observation stations	Early warning systems	Water supply and sanitation capacity	Transportation network capacity	Telecommunication capacity	Electricity generation and distribution systems	Natural gas distribution and storage systems
Main Factors	Weather condition									Environmental				Basin characteristics						Flood characteristics			Institutional capacity						Urban Infrastructure				
Sohn (2006)								↘					↘																	↘			
Chen et al. (2015)																														↘			
Veldhuis et al. (2011						↘			↘	↘				↘	↘		↘				↘				↘				↘				
Zhang and You (2014									↘														↘	↘	↘			↘	↘	↘	↘	↘	
Parker (1995)						↘	↘		↘			↘	↘	↘				↘		↘	↘							↘		↘	↘		
Gruntfest and Huber (1989																↘																	
Mahe et al. (2005)						↘								↘			↘	↘															
Thouret et al. (2014)						↘	↘	↘	↘		↘						↘	↘		↘	↘	↘			↘	↘			↘	↘	↘	↘	
Vari et al. (2003)	↘					↘		↘			↘		↘		↘		↘				↘	↘	↘	↘	↘			↘	↘	↘			
Knebl et al. (2005)	↘					↘	↘	↘					↘					↘		↘													
Correia et al. (1998)									↘	↘		↘	↘			↘	↘						↘	↘	↘			↘	↘				
Jeong and No (1994)						↘													↘	↘		↘											
Dutta et al. (2003)						↘			↘				↘	↘	↘	↘	↘	↘		↘	↘	↘		↘	↘	↘	↘	↘	↘	↘	↘	↘	↘
Junker et al. (1999)	↘		↘	↘		↘		↘												↘	↘												
Sepetçioğlu (2013)		↘	↘	↘	↘	↘	↘				↘		↘	↘		↘		↘		↘	↘	↘	↘	↘	↘	↘	↘	↘					
Kadıoğlu (2008)	↘					↘	↘	↘	↘				↘	↘		↘	↘	↘		↘	↘	↘	↘	↘	↘	↘	↘	↘		↘			
Green et al. (2000)	↘		↘	↘		↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘		↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘
Bahadır (2011)	↘																				↘												
Ozcan (2006)	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘		↘		↘		↘			↘	↘			↘				↘	↘			
WMO (2008)	↘				↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘			↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	
Nied et al. (2014)						↘		↘	↘				↘							↘	↘		↘	↘	↘	↘	↘	↘	↘				
Ahmad and Simonovic (2000																	↘			↘	↘				↘			↘	↘				
Smith (1994)			↘	↘	↘		↘						↘							↘	↘	↘											
Scheuer et al. (2011)											↘		↘							↘					↘	↘				↘			
Costa et al. (2004)						↘	↘	↘	↘		↘		↘	↘		↘					↘				↘				↘	↘			
Dwyer et al. (2004)								↘	↘														↘	↘		↘	↘						
Chang et al. (2009)	↘				↘	↘		↘	↘	↘	↘	↘	↘	↘	↘			↘		↘			↘	↘	↘	↘		↘					
Špitalar et al. (2014)	↘					↘	↘	↘	↘			↘				↘				↘	↘	↘						↘					
Tingsanchali (2012						↘		↘		↘	↘	↘	↘		↘		↘			↘	↘	↘	↘	↘	↘	↘	↘	↘	↘				
Sayers et al. (2003)						↘		↘	↘			↘	↘			↘		↘		↘				↘		↘		↘	↘	↘			
Ruin et al. (2008)	↘					↘	↘	↘						↘	↘	↘	↘	↘		↘	↘	↘		↘			↘	↘					
Mirza (2002)	↘					↘	↘	↘	↘				↘			↘	↘			↘	↘	↘							↘	↘			
Jonkman and Kelman (2005	↘		↘	↘				↘												↘	↘	↘			↘			↘					
Kelman and Spence (2004)	↘		↘	↘				↘	↘			↘		↘				↘		↘	↘	↘						↘					
Dang et al. (2011)								↘	↘		↘		↘							↘	↘	↘			↘	↘		↘	↘	↘		↘	

Table 4.1 Frequency analysis of the risk factors affecting flood loss level (cont'd)

	L1	Residential building rate	✔			✔		✔	✔		✔	✔		✔	✔		✔	✔	✔		✔	✔	✔		✔		✔		✔	✔				✔	✔		
	L2	Commercial building rate						✔	✔		✔			✔	✔				✔		✔		✔		✔				✔	✔				✔	✔		
	L3	Industrial building rate	✔						✔					✔				✔					✔		✔					✔				✔	✔		
Land use	L4	Agricultural usage rate	✔			✔			✔		✔		✔		✔	✔	✔	✔	✔		✔		✔		✔		✔		✔				✔				
	L5	Public infrastructure rate	✔			✔			✔	✔				✔				✔			✔		✔		✔				✔	✔				✔			
	L6	Historical and archeological sites	✔																		✔						✔		✔	✔							
	L7	Special public use building rate	✔					✔						✔							✔									✔			✔	✔			
	L8	Structuring rate in flood danger zone	✔					✔	✔		✔				✔		✔	✔			✔	✔					✔		✔	✔				✔			
	S1	Structural type		✔					✔						✔			✔			✔				✔					✔							
	S2	Durability of building		✔											✔			✔							✔					✔							
	S3	Age of building													✔															✔					✔		
	S4	Floor area coefficient																							✔												
Superstructure capacity	S5	Existence of basement housing													✔						✔									✔			✔	✔	✔		
	S6	Rate of building with insurance	✔	✔				✔			✔	✔			✔			✔			✔				✔		✔		✔				✔		✔		
	S7	Rate of building without permission from municipality																			✔	✔							✔								
	S8	Floor covering type		✔											✔			✔			✔						✔										
	S9	Fortification to the flooded buildings															✔	✔				✔			✔												
	D1	Income level	✔			✔						✔		✔	✔			✔			✔								✔	✔			✔	✔			
	D2	Population density	✔						✔	✔	✔	✔	✔			✔	✔	✔	✔		✔	✔	✔				✔		✔	✔			✔	✔	✔		
	D3	People in need and health level	✔		✔		✔					✔	✔	✔		✔		✔			✔												✔	✔			
	D4	Level of education	✔		✔			✔		✔		✔	✔					✔			✔	✔	✔				✔						✔				
	D5	Public awareness	✔		✔			✔		✔		✔	✔					✔			✔	✔	✔				✔										
	D6	Population age	✔		✔		✔					✔		✔																				✔			
	D7	Flood experience	✔		✔							✔			✔						✔						✔										
	D8	Swimming ability			✔																																
Demographic and social	D9	Public participation							✔			✔	✔					✔			✔	✔					✔										
	D10	Tenure type and rate										✔																									
	D11	Gender			✔		✔					✔						✔															✔	✔			
	D12	Use of alcohol			✔																																
	D13	Household type										✔													✔								✔				
	D14	Car ownership										✔																					✔	✔			
	D15	English language skill										✔																									
	D16	Debt and saving				✔						✔		✔							✔									✔				✔			
	D17	Employment rate										✔		✔															✔				✔				
	E1	Water pollution risk	✔	✔	✔						✔			✔				✔			✔		✔						✔					✔			
Ecological	E2	Soil pollution and erosion risk	✔	✔							✔		✔	✔			✔	✔	✔		✔	✔	✔		✔				✔								
	E3	Flora associated risk	✔	✔							✔		✔	✔			✔	✔	✔		✔	✔	✔		✔												
	E4	Fauna associated risk																✔																			
	A1	Location of the population			✔	✔	✔			✔		✔		✔				✔			✔			✔	✔					✔			✔	✔			
Accessibility	A2	Accessibility to services										✔		✔				✔			✔									✔		✔	✔				✔
	A3	Time of flood		✔	✔	✔	✔			✔	✔		✔	✔		✔					✔	✔	✔					✔		✔				✔			

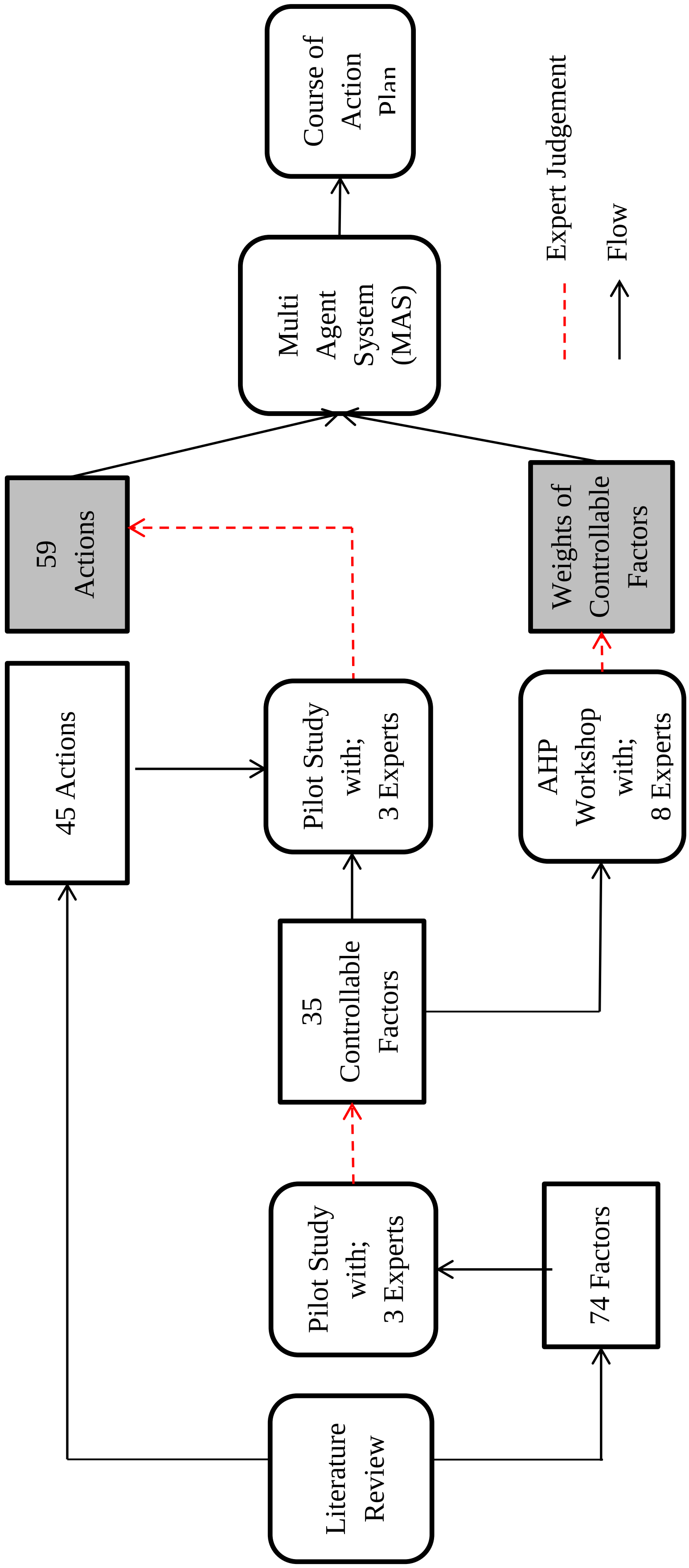

Figure 4.1 Steps in data collection

4.2.1 Suitability of the Main and Sub Factors

Some of the factors, for the purpose of not to focus on ineffectual ones, were eliminated from the pilot study with 3 experts. Some of the main factors were excluded from the study as they are not manageable. Weather conditions, environmental, basin characteristics, flood characteristics and accessibility main factors were excluded from the remaining study and workshop, so as to focus controllable factors. Structuring rate in flood danger zone sub factor was eliminated by experts indicating that other land use factors are corresponding to this factor. Fortification to the flooded building factor was eliminated in superstructure capacity main factor as it indicates the durability of building, which is also one of the superstructure capacity factors. The biggest exclusion occurs in demographic and social factors by 12 eliminations, which are flood experience, swimming ability, public participation, tenure type and rate, gender, use of alcohol, household type, car ownership, English language skill, debt and saving and employment rate. The comments of experts on these factors were mainly that the effect of changing in the condition of them is too ambiguous, for instance flood experience. One experienced flood more is more vulnerable as exposed to flood more, however, experience make this person more resilient. They addressed that the measurement of public participation is so hard. Most of them were seen by experts as having just subtle impacts, such as English language skill, gender, household type, use of alcohol and swimming ability. Debt and saving, employment rate, car ownership and tenure type have direct link to income level, they added. Moreover they indicate that not age of population, people in need is important. As a result, 6 main and 35 sub factors were choosen to work on. Controllable factors affecting flood loss level and the hierarchy of them can be seen at Figure 4.2. Factors in the figure were asked to the experts in the context of AHP.

4.2.2 Expert Profile

A workshop was held with 8 experts in the context of brainstorming. The profile of the participant experts of workshop can be seen at Table 4.2. Experts were tried to be choosen from the variety of the departments associated with flood risk reduction. 3 experts of pilot study can also be seen at Table 4.2

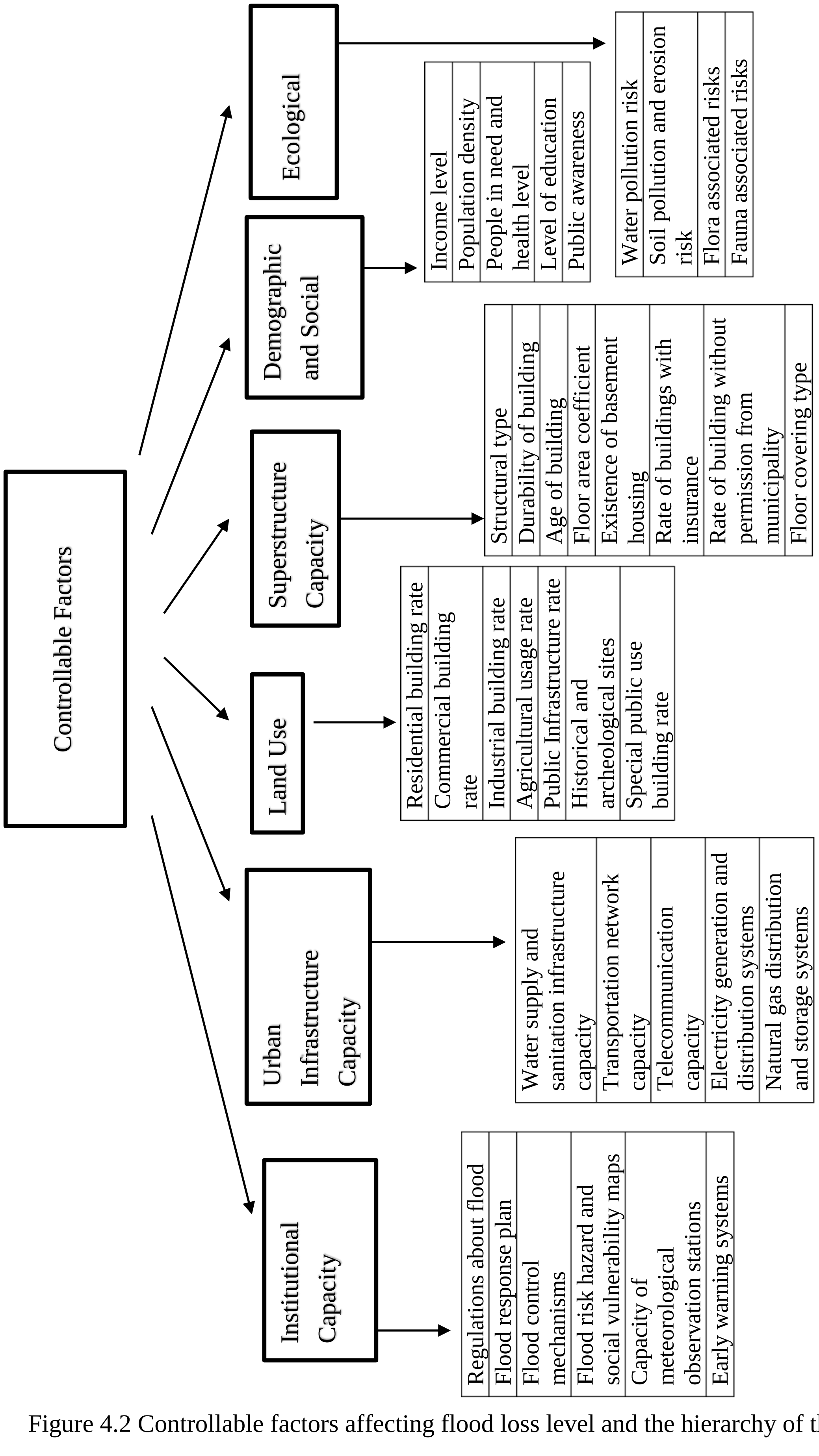

Figure 4.2 Controllable factors affecting flood loss level and the hierarchy of them

Table 4.2 Profile of experts participated in AHP workshop and pilot study

Study	Institution	Background	Position	Experience (year)
AHP Workshop	University	Hydraulics	Faculty member	20
	University	Hydraulics - Environmental	Faculty member	15
	Local municipality	Planning - Environmental	Managerial level	18
	Local municipality	Planning	Managerial level	21
	Local municipality	Civil engineering	Managerial level	24
	Institution for water and sewerage administration	Planning - Environmental - Civil engineering	Managerial level	30
	Institution for disaster coordination	Geomatic-Meteorological	Managerial level	26
	Institution for disaster and emergency management	Civil engineering	Managerial level	28
Pilot Study	University	Disaster - Geotechnical	Faculty member	32
	University	Disaster - Environmental	Faculty member	25
	Institution for disaster coordination	Meteorologic-Planning	Managerial level	22

4.2.3 Analytical Hierarchy Process (AHP)

AHP is a method for evaluating parameters and making decisions in complex problems. In AHP, all elements are compared with each other and then the impact levels of parameters are calculated. AHP was first introduced by Thomas L. Saaty in the 1970s and it can be used in all decision making problems. AHP could give results with both qualitative and quantitative data. Moreover, it can be run by group of people as a brainstorming activity as well. AHP allows 1-9 scale comparison weights for elements with each other, while scale 1 means the equal importance with each other, scale 9 means extremely more important than other. Definitions of the typical 9 scale comparisons for AHP taken from [139] are shown in Table 4.3.

Table 4.3 Definitions of the 9 scale comparison points of AHP [139]

Rating Scale	**Definition**
1	Equal importance of two parameters
2	Equally to moderately importance of one over another
3	Moderate importance of one over another
4	Moderately to strongly importance of one over another
5	Strong importance of one over another
6	Strongly to very strongly importance of one over another
7	Very strong importance of one over another
8	Very strongly to extremely importance of one over another
9	Extreme importance of one over another

Table 4.4 shows an example of AHP matrix by 3 parameters which are A, B and C. from the light of the table, the respondent may want to mention:

- Parameter A is moderately more important than parameter B
- Parameter A is strongly less important than parameter C
- Parameter B and C have equal importance

Table 4.4 An example of AHP pairwise comparison matrix

	A	**B**	**C**
A	1.0	**3**	**1/5**
B	1/3	1.0	**1**
C	5	1	1.0

Consistency ratio is the core factor in AHP, if it is measured less than 0.1 it means it is acceptable, else, there is a need to hold pairvise comparisons again because the results are too close to randomness.

The distribution of the scores in reciprocal matrix represented as [140]:

$$A = [a_{ij}] = \begin{Bmatrix} 1 & a_{ij} \dots & a_{1n} \\ 1/a_{ij} & \dots & \dots \\ 1/a_{1n} & \dots & 1 \end{Bmatrix} \tag{4.1}$$

Once the matrix A is gathered, then it is necessary to calculate normalized form of it and weights of each criterion.

$$a'_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \tag{4.2}$$

$$w_i = \frac{\sum_{k=1}^{n} a'_{ik}}{n} \tag{4.3}$$

$$CI = (\lambda_{max} - n)/(n-1) \tag{4.4}$$

$$CR = CI/RI \tag{4.5}$$

Where w_i is the weight of criterion i, λ is eigenvalue, R.I. is an average random consistency derived from a sample sized 500 given by Saaty (1987), which can be seen at Table 4.5.

Table 4.5 Random consistency index numbers for different dimensions [141]

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random consistency index (RI)	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

4.3 Results of the AHP Workshop

The data used in AHP study was taken from aforementioned AHP workshop. AHP matrices at Appendix A were given to experts for them to see pairvise comparisons. As experience of the experts is a crucial in judgements [142], in AHP study, when calculating the weights, level of experience was also included exponentially, which makes it better to focus more on experienced participants. For instance, if 5-year-experienced participant A gives 2.5 and 10-year-experienced participant B gives 4 in weight to the comparison of parameter P_1 and P_2, overall weight is calculated as: $w = [(2.5)^5 * (4)^{10}]^{(\frac{1}{15})}$. Holding whole workshop for this study takes approximately two hours.

The results of the AHP study of main and sub factors in normalized, idealized and percentage types, with their inconsistency ratio, can be seen at Table 4.6 – 4.12. Table 4.6 shows the results of main factors while Table 4.7-4.12 shows that of sub factors.

Normalized values indicate basically the relative weights of factors while idealized values addresses the importance of each parameter by considering the most important ones. It is seen that flood control mechanisms in institutional; water supply and sanitation capacity in urban infrastructure; special public use building rate in land use; existence and condition of basement in superstructure; awareness in demographic and social; water pollution risk in environmental and ecological factors were found the most impactful factors in its inner classes by 35.9, 53.0, 22.4, 22.2, 34.2, 39.8 per cent respectively.

In terms of main factor cluster, urban infrastructure is found to be the most important main factor by 33.7 per cent, followed by land use main factor by 26.7 per cent. In main class environmental and ecological, demographic and social main factors are seen as the least important ones by 4.8 and 7 per cent respectively (Table 4.6)

In institutional capacity main factor, I2, which stands for flood response plan, is the second most important factor by 19.9 per cent. However, there is a huge difference between first and second most important factors which is nearly 16 per cent. In this main factor I5, capacity of meteorological observation station, is seen as the least important one by 7.2 per cent (Table 4.7).

In terms of urban infrastructure main factor, U2, transportation network capacity, is found to be the second most important factor, however, again there is a huge differences between that of first and second factors by nearly 28.8 per cent. The least important factor, not surprisingly, was concluded as U5, natural gas systems capacity by nearly 5.3 per cent (Table 4.8).

In the context of land use main factor, even though special public use building rate gets the highest score in by 22.4 per cent, the importance of residential building rate and public infrastructure rate is so closed to it by 20.2 and 20.1 per cent respectively. In terms of the least important ones, L4, agricultural usage rate, and L2, commercial building rate, are at the top of the all factors, by 6.6 and 8 per cent respectively (Table 4.9)

In superstructure capacity main factor, S5, existence and condition of basement, is followed by S2, S4 and S8 by 14, 12.9 and 12.7 per cent respectively. Surprisingly, S6, rate of building with insurance and S3, age of building are concluded as the least important ones by 7.2 and 9 per cent respectively (Table 4.10)

In demographic and social factors, D4, level of education is found to be the second most important factor by 25.5 per cent. D1, average income level and D2, population density is in reverse, found to be the least important ones by 11.5 and 13.4 per cent (Table 4.11)

At last, in environmental and ecological main factor, after E1, water pollution risk, E2, soil pollution and erosion risk is seen as the second most important sub factor by 31.5 per cent. Fauna and Flora associated risk factors (E4 and E3) in reverse found to be the least important ones by 10.5 and 18.2 per cent (Table 4.12).

Table 4.6 Weights of main factors

ID	Factors	Normalized	Idealized	Percent
I	Institutional Capacity	0,1614	0,4796	16,1%
U	Urban Infrastructure	0,3365	1,0000	33,7%
L	Land Use	0,2669	0,7931	26,7%
S	Superstructure Capacity	0,1175	0,3490	11,8%
D	Demographic and Social	0,0701	0,2083	7,0%
E	Ecological	0,0477	0,1417	4,8%
			Inconsistency:	**0,02143**

Table 4.7 Weights of institutional capacity factors

ID	Factors	Normalized	Idealized	Percent
I1	Regulations about Flood	0,1433	0,3998	14,3%
I2	Flood Response Plan	0,1985	0,5536	19,9%
I3	Flood Control Mechanisms	0,3586	1,0000	35,9%
I4	Flood Risk Hazard and Social Vulnerability Maps	0,1084	0,3022	10,8%
I5	Capacity of Meteorological Observation Stations	0,0721	0,2012	7,2%
I6	Early Warning Systems	0,1190	0,3320	11,9%
			Inconsistency:	**0,0130**

Table 4.8 Weights of urban infrastructure factors

ID	Factors	Normalized	Idealized	Percent
U1	Water Supply and Sanitation Infrastructure Capacity	0,5297	1,0000	53,0%
U2	Transportation Network Capacity	0,2575	0,4861	25,8%
U3	Telecommunication Capacity	0,0740	0,1398	7,4%
U4	Electricity Generation and Distribution Systems	0,0857	0,1619	8,6%
U5	Natural Gas Distribution and Storage Systems	0,0530	0,1000	5,3%
			Inconsistency:	**0,03582**

Table 4.9 Weights of land use factors

ID	Factors	Normalized	Idealized	Percent
L1	Residential Building Rate	0,2025	0,9048	20,2%
L2	Commercial Building Rate	0,0796	0,3557	8,0%
L3	Industrial Building Rate	0,1040	0,4649	10,4%
L4	Agricultural Usage Rate	0,0659	0,2946	6,6%
L5	Public İnfrastructure Rate	0,2015	0,9002	20,1%
L6	Historical and Archaeological Sites	0,1227	0,5483	12,3%
L7	Special Public Use Building Rate	0,2238	1,0000	22,4%
			Inconsistency:	**0,0165**

Table 4.10 Weights of superstructure capacity factors

ID	Factors	Normalized	Idealized	Percent
S1	Structural Type	0,11949	0,53719	11,9%
S2	Durability of Building	0,13968	0,62796	14,0%
S3	Age of Building	0,08993	0,40429	9,0%
S4	Floor Area Coefficient	0,12882	0,57912	12,9%

Table 4.10 Weights of superstructure capacity factors (cont'd)

S5	Existence of Basement	0,22243	1,00000	22,2%
S6	Rate of Building with Insurance	0,07167	0,32222	7,2%
S7	Rate of Building without Permission from Municipality	0,10076	0,45300	10,1%
S8	Floor Covering Type	0,12722	0,57193	12,7%
			Inconsistency:	**0,0103**

Table 4.11 Weights of demographic and social factors

ID	Factors	Normalized	Idealized	Percent
D1	Income Level	0,1153	0,3371	11,5%
D2	Population Density	0,1341	0,3918	13,4%
D3	People in Need and Health Level	0,1539	0,4499	15,4%
D4	Level of Education	0,2545	0,7439	25,5%
D5	Public Awareness	0,3422	1,0000	34,2%
			Inconsistency:	**0,0042**

Table 4.12 Weights of ecological factors

ID	Factors	Normalized	Idealized	Percent
E1	Water Pollution Risk	0,3985	1,0000	39,8%
E2	Soil Pollution and Erosion Risk	0,3149	0,7903	31,5%
E3	Flora Associated Risk	0,1817	0,4559	18,2%
E4	Fauna Associated Risk	0,1049	0,2633	10,5%
			Inconsistency:	**0,0022**

Inconsistencies and standard deviation of the factors were summarized at Table 4.13. As it can be seen, participants were stick to what they have already said mostly in environmental and ecological, and demographic and social factors by 0.0022 and 0.0042 inconsistencies respectively. However, they might find it harder to evaluate the importance of main and urban infrastructure factors by 0.0214 and 0.0358 inconsistencies respectively. Even though it can change by the type of main factor, the workshop results are acceptable as all the inconsistencies are less than 0.1. In terms of standard deviation, as it can be seen, urban infrastructure factors have the highest score because of very high score of U1 and relatively high score of U2 compared to others. On the other hand, land use and superstructure capacity factors have the least standard deviation by nearly 0.060 and 0.042 respectively.

Table 4.13 Inconsistency and standard deviation of AHP

ID	Factors	Inconsistency	Standard Deviation
Main	Main Parameters	0,0214	0,1039
I	Institutional Capacity	0,0130	0,0939
U	Urban Infrastructure Capacity	0,0358	0,1803
L	Land Use	0,0165	0,0602
S	Superstructure Capacity	0,0103	0,0424
D	Demographic and Social	0,0042	0,0858
E	Ecological	0,0022	0,1140

As a result, priorities of each of the sub factors can be seen at Table 4.14 from the most important ones to the least. In terms of sub factors, 2 urban infrastructure, 2 land use and 1 institutional capacity factors were seen at the head of the table, which means there is a strong impact of these factors. Especially U1 has 0.1783 of overall weights subjected to comparisons, which means it strongly dominates the destructive impacts of flooding.

Moreover, U1 sub factor is more important than 4 of the 6 main factors itself, which is also a remarking point. Besides, U2 have also more impact than 2 of the main factors. From the other side of the table, E4, which stands for fauna associated risk, gets the minimum score in overall by 0.5% followed by average income level, rate of building with insurance and flora associated risk by 0.81, 0.84 and 0.87% respectively.

Table 4.14 Priorities of sub factors

ID	Factors	Normalized By Cluster	Limiting	Idealized	Percent
U1	Water Supply And Sanitation Infrastructure Capacity	0,1783	0,0891	1,0000	17,83%
U2	Transportation Network Capacity	0,0867	0,0433	0,4861	8,67%
L7	Special Public Use Building Rate	0,0597	0,0299	0,3350	5,97%
I3	Flood Control Mechanisms	0,0579	0,0289	0,3246	5,79%
L1	Residential Building Rate	0,0540	0,0270	0,3032	5,40%
L5	Public Infrastructure Rate	0,0538	0,0269	0,3016	5,38%
L6	Historical and Archaeological Sites	0,0327	0,0164	0,1837	3,27%
I2	Flood Response Plan	0,0320	0,0160	0,1797	3,20%
U4	Electricity Generation and Distribution Systems	0,0289	0,0144	0,1618	2,89%
L3	Industrial Building Rate	0,0278	0,0139	0,1558	2,78%
S5	Existence of Basement	0,0261	0,0131	0,1466	2,61%
U3	Telecommunication Capacity	0,0249	0,0125	0,1398	2,49%
D5	Public Awareness	0,0240	0,0120	0,1345	2,40%
I1	Regulations about Flood	0,0231	0,0116	0,1298	2,31%
L2	Commercial Building Rate	0,0212	0,0106	0,1192	2,12%
I6	Early Warning Systems	0,0192	0,0096	0,1078	1,92%
E1	Water Pollution Risk	0,0190	0,0095	0,1066	1,90%
D4	Level of Education	0,0178	0,0089	0,1001	1,78%
U5	Natural Gas Distribution and Storage Systems	0,0178	0,0089	0,1000	1,78%

Table 4.14 Priorities of sub factors (cont'd)

L4	Agricultural Usage Rate	0,0176	0,0088	0,0987	1,76%
I4	Flood Risk Hazard and Social Vulnerability Maps	0,0175	0,0087	0,0981	1,75%
S2	Durability of Building	0,0164	0,0082	0,0921	1,64%
S4	Floor Area Coefficient	0,0151	0,0076	0,0849	1,51%
E2	Soil Pollution and Erosion Risk	0,0150	0,0075	0,0843	1,50%
S8	Floor Covering Type	0,0149	0,0075	0,0838	1,49%
S1	Structural Type	0,0140	0,0070	0,0787	1,40%
S7	Rate of Building without Permission from Municipality	0,0118	0,0059	0,0664	1,18%
I5	Capacity of Meteorological Observation Station	0,0116	0,0058	0,0653	1,16%
D3	People in Need and Health Level	0,0108	0,0054	0,0605	1,08%
S3	Age of Building	0,0106	0,0053	0,0592	1,06%
D2	Population Density	0,0094	0,0047	0,0527	0,94%
E3	Flora Associated Risk	0,0087	0,0043	0,0486	0,87%
S6	Rate of Building With Insurance	0,0084	0,0042	0,0472	0,84%
D1	Income Level	0,0081	0,0040	0,0453	0,81%
E4	Fauna Associated Risk	0,0050	0,0025	0,0280	0,50%

4.4 Determination of Flood Mitigation Measures

By acquiring the results of AHP process, because the actions, interventions and responsibilities are aimed to be achieved, there is a need to have plan of these interventions related to all factors. In general flood management activities are based on land use planning, creating control measures of runoff, storage of flood water, flood warning, insurance policies, flood resistance of properties, maintenance of all flood defense systems [1]. Price and Vojinovic (2008) divided flood management activities into pre, during and post disaster activities. While pre-disaster include activities as risk analysis, actions and awareness, during activities are flood warning, evacuation and services. Post disaster activities, on the other hand, are damage assessment, reconstruction and mitigation activities [76]. In this study, we focus on disaster mitigation measures.

From the light of the factors, at the pilot study, 59 strategic actions to mitigate flood risk were determined, which can be seen at Table 4.15, with some references. Each action has some social, economic and environmental aspects of it, as experts in pilot study expressed. As these actions are related to mitigation and can be taken beforehand, their ID is named as B-, standing for before. Each action was subjected to one of the round class, in terms of duration of the action, cost of action and effort that is needed for corresponding action.

Round class of actions were determined according to interview with 2 experts from an institution for disaster coordination. Table 4.16 shows the meaning of each of the rounds, in multi agent modeling. For instance if the round class is 2 for an action, it means in MAS model, it will take 20 round, or 20 steps to be finished.

For the actions, three data is needed which can change case by case. 1) Economic, social and environmental weights of actions, 2) current condition of actions, indicating whether this activity has started before, if so, how much has been done, and 3) good-bad conditions, indicating that how much endurance of area can change if activity is done or not, in other words, how much effect that activity can have to mitigate flood risk. These 3 types of data can be asked for different cases, so that the model can be suited for each area, by changing priorities of activities.

4.5 Development of the Integrated Multi Agent Risk Management Platform

As a result of the flood mitigation factors and measures with their round classes, there is a need to allocate tasks to the responsible agents. Figure 4.3 shows the integration of AHP and multi agent system (MAS) in this study.

Table 4.15 Flood disaster mitigation measures

Code	Flood mitigation measures	Round class	Some references
B1	Increase the capacity of roads	2	[132]
B2	Maintenance of water supply facilities	1	[7], [102]
B3	Maintenance of storm water drainage facilities	1	[102]
B4	Increase the capacity of storm water drainage facilities	4	[102]
B5	Maintenance of transportation network	1	[7], [132]
B6	Improvement of telecommunication facilities and warning dissemination systems	3	[7], [118], [123], [132]
B7	Improvement of electricity generating and distribution systems	4	[118]
B8	Improvement of natural gas transmission and distribution systems	4	[118]
B9	Increase maintenance of dams' capacity	3	[84]
B10	Build flood control mechanism places near dams	3	[84]
B11	Embed early warning system on dams	2	[84]
B12	Build storm water detention mechanism and maintain risky areas (i.e. storm water detention ponds, retention basin)	4	[102], [143]
B13	Build flood control mechanism in coastal sides (tidal or storm surge barriers)	2	[144]
B14	Change town planning conditions according to imperviousness	5	[118], [144]

Table 4.15 Flood disaster mitigation measures (cont'd)

B15	Increase afforestation	1	[118], [123]
B16	Terrace places having erosion probability	1	[123]
B17	Vegetate soil without any vegetation	2	[123]
B18	Save more funds for people with low income	2	[144]
B19	Train public in flood disaster and increase the awareness of them	1	[7], [118], [123]
B20	Control industrial and other buildings emitting chemical or hazardous waste if there is a possibility of touch to flood water	2	[102]
B21	Promote people living in floodplains to move (land use control to prevent occupation of high risk areas)	4	[7]
B22	Increase the legal conditions and regulations (building code in terms of material use and so on) over flooding	2	[7], [73], [118], [123], [143]
B23	Increase the capacity of water supply facilities	4	[118]
B24	Implement flood hazard and risk maps and improve them	2	[118], [143]
B25	Improve flood resistance in residential buildings	4	[118], [143]
B26	Improve flood resistance in commercial buildings	4	[144]
B27	Improve early warning systems	2	[73], [84], [118], [119], [123], [143]
B28	Increase the number and capacity of secondary roads in flood prone areas	4	[135]
B29	Increase and develop levees, dykes, embankments and other flood control mechanisms	3	[7], [84], [143]

Table 4.15 Flood disaster mitigation measures (cont’d)

B30	Increase the capacity of drainage and create system for optimum soil water level (irrigation) for agricultural areas	3	[118], [144]
B31	Promote people to insure their properties	2	[7], [75], [84]
B32	Recruit special rescue team for animals (fauna)	1	[84], [145]
B33	Control the drainage of roads for their capability of carrying water to levees (storm water drainage channels, waterway systems)	3	[118]
B34	Increase the maintenance of levees, dykes, embankments and other flood control mechanisms	1	[84]
B35	Increase the capacity of meteorological observation station	3	[84], [118], [119]
B36	Change the covering with higher water insulation type (flood proofing)	2	[118]
B37	Develop flood response plan and increase the capacity of emergency response team and vehicles	2	[7], [118], [143]
B38	Dredge, widen or remediate streams and channels	5	[118]
B39	Put an area in urban regeneration site	5	[143]
B40	Increase the number of schools in the area	4	[7], [118], [123]
B41	Improve the resistance of historical places	3	[2]
B42	Increase the number of health centres	4	[102]
B43	Increase the number of parks and open spaces	3	[102]
B44	Improve resistance of industrial areas	3	[118]
B45	Improve flood resistance in public infrastructures	3	[118]

Table 4.15 Flood disaster mitigation measures (cont'd)

B46	Improve flood resistance in special public use buildings (hospital, schools, parks etc.)	3	[118]
B47	Change the building code in terms of structural material	2	[118], [135]
B48	Promote people to change building material or to build flood walls so as to increase durability to flooding	2	[81], [102]
B49	Change floor area coefficient in the area	2	[125]
B50	Change building code in terms of basement	2	[81]
B51	Help low-income people to insure their properties	2	[7], [84], [118]
B52	Create and train special rescue team for disabled people	1	[118]
B53	Open face to face or online courses in any subject for people to increase the level of education	1	[136]
B54	Create a team to care flora in case of flooding, preserve biodiversity	1	[84], [145]
B55	Construction of diversion channel	4	[84]
B56	Recruit personnel for emergency services and for community volunteer groups	1	[7]
B57	Increase the capacity of waste water drainage facilities	4	[102]
B58	Help people to have permission from municipality	1	[143]
B59	Promote people to reinforce their buildings and houses	2	[143]

Table 4.16 Round classes

Round class	Name of the period	Round in MAS	Meaning - in terms of time, cost and effort (TCE)
1	little	10	It requires little TCE
2	moderate to little	20	It requires moderate to little TCE
3	moderate	50	It requires moderate TCE
4	much	100	It requires much TCE
5	extreme	250	It requires extreme TCE

4.5.1 Multi Agent System (MAS)

The term multi agent system (MAS) refers to a self-organized system, consisting of several intelligent agents cooperating with each other. Besides, it is not always the same with agent-based modeling (ABM). In terms of MAS, an agent is defined as an entity that holds continuous and autonomous actions in agent environments in which other processes are taken place by other agents in the same environment [146]. In multi agent systems, mechanisms allowing agents to coordinate their activities and negotiate with other agents at run time is needed [147]. Apart from that, in multi agent systems the main objective of an agent is its own welfare instead of focusing on common goal [147]. Intelligent interactions are also required in MAS and the main concepts of intelligent interactions are cooperation, coordination and negotiation. During the last decades MAS was used in various domains from power system management to business process management, from flood forecasting to solving difficult optimization problems [148].

The difference between classical distribution systems and MAS is that in MAS, agents are self-interested in which one can execute an action increasing its utility while decreasing some others. There are individual or organizations that represents their interests. Therefore, MAS researches are concerned with the wider problems designing systems or societies of autonomous agents [147].

4.5.1.1 Multi Agent Systems Applications

By focusing on cooperation, autonomous and learning properties of agents, despite the developments of multi agent systems and agent-based modeling; there have been a few studies on the area of construction [149]. As in real world all stakeholders in any area lacks sufficient resources and capabilities, they should interact with others to maximize their utilities [149]. In construction management, there has been several sort of use of MAS such as project organization [150], collaborative design [151], dynamic scheduling [152], dispute resolution [153], negotiation [154] and site management [155]. In construction process, as well as disaster management, the environment is extremely dynamic as tasks and resources may change over time. Thus dynamic adaptation of MAS is very advantageous in scheduling [149].

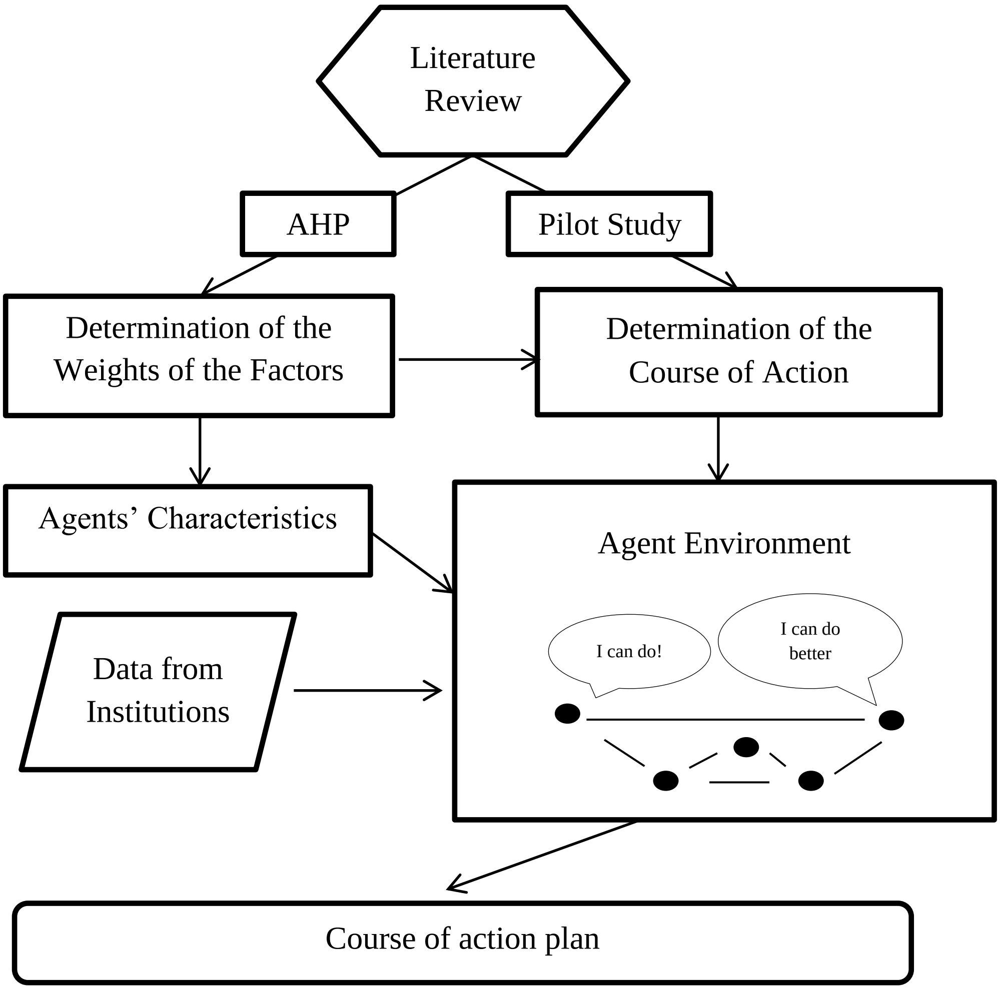

Figure 4.3 Integration of AHP and MAS

In terms of scheduling, Kim and Paulson (2003) studied on facilitating distributed coordination of subcontractor in project schedule changes and addressed that by having such an approach, increase in social welfare is inevitable as well as individual interests [156]. In that study, a compensatory negotiation strategy is illustrated based on utilities with regard to utility of agents, negotiation of interacting agents, messaging between agents, to evaluate other alternatives. Taghaddos et al. [157] presents simulation based auction protocol (SBAP) to solve the problematic in resource scheduling in large projects. In this study agents increase their own utility by acquiring combination of resources whereas auctioneer looks at the entire system and allocate tasks in order to increase overall utility. The main concept in the study is multi agent resource allocation (MARA) rather than multi agent system (MAS). Allocation of resources in MARA is known as “auction protocol” where agents submit their preferences in terms of different combination of resources so that they could maximize their utilities. An auctioneer then decides on the allocation so as to maximize overall utility of the system [158].

In terms of task allocation, Chu et al. (2009) developed a MAS model to have collaborative 3D design in construction industry [159], in which the system includes server and clients as agents to achieve specific tasks. Watkins et al. (2009) developed agent-based model to analyze labor efficiency by using bottom-up approach [160]. By doing that task allocation can be planned more accurately [149].

In terms of disaster management, agent based modeling was used by Dawson et al. (2011) to create effective flood incident management. Developed model integrates remotely sensed information on topography, building and transportation network. By integrating hydrodynamic modeling within it, vulnerability of individuals in different storm conditions or flood warning time becomes achievable [11]. Yang and Xu (2012) examined sequential games in order to find optimal relief plan to provide decision makers according to experts’ preference over plans in disastrous situations [161].

4.5.1.2 Agents and Agent Environment

An agent is a computer system that tries to achieve its goal in an environment, and that is capable of autonomously execute actions in this environment in order to meet its designed objectives [147]. Autonomy means that there is no need of human guidance for agent to execute some actions [162].

As it is shown at Figure 4.4, an agent takes sensory as an input from the environment, and executes some actions that affect this environment. The interaction is usually an ongoing, non-terminating integration [147]. This means that the same actions executed by the same agent may result in different outputs.

There are mainly three capabilities that an intelligent agent is capable of:

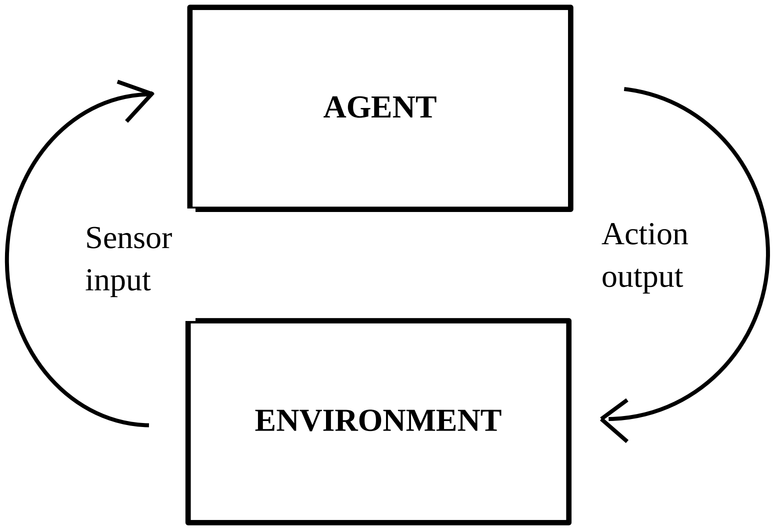

Figure 4.4 Agent with its environment [147].

Reactivity: agents are capable of perceive some knowledge from its environment and responds for its designed objectives.

Proactivity: agents could execute actions initiatively for their designed goal.

Social ability: agents are capable of interacting with other agents, in order to achieve their designed objectives [163]

From the light of above, being goal directed may be achieved easily, however, being goal directed and reactive together could be hard in some extents [147].

On the other hand, agents could have belief-desire-intention (BDI) logic for their actions. Belief refers to the current situation of an agent, while desire refers to the goal of it, and intention refers to the actions [135]. It is known as BDI model and it does not prescribe a specific implementation of a computer program. However, there are different sort of implementations that was used successfully [164].

In terms of environment, it can be differentiated for different main goal. The main four changes in agent environments are: accessibility, determinism, dynamism and continuity [147].

First, it can either be accessible or inaccessible. In accessible environment, agent has full view of its environment and there is no need for it to estimate environmental circumstances. In inaccessible environment, by contrast, it has to estimate its environment in order to have knowledge. In our study accessible environment is chosen.

Second, the environment could be deterministic or non-deterministic. In deterministic environment, each action has distinct results, while in non-deterministic environments the results could change. In our study, deterministic environment is choosen.

An environment could also be static or dynamic. In dynamic environment, even though an agent performs no action between times t_0 and t_1, this agent cannot assume that the environment in these times are the same. In this study dynamic environment is chosen.

The last, an environment could be discrete or continuous. If there are a finite number of actions, the environment is discrete, else continuous. In our study, environment is discrete.

Figure 4.5 shows the utility-based agent and its environment addressed by Russel and Norvig (2016). It indicates that agents choose their activities according to utility they gain due to this action and environment directly change because of the action of an agent [165]. Agents in their environment are not just willing to increase their own benefit; they also want to maximize global utility, making MAS worthwhile for disaster management processes.

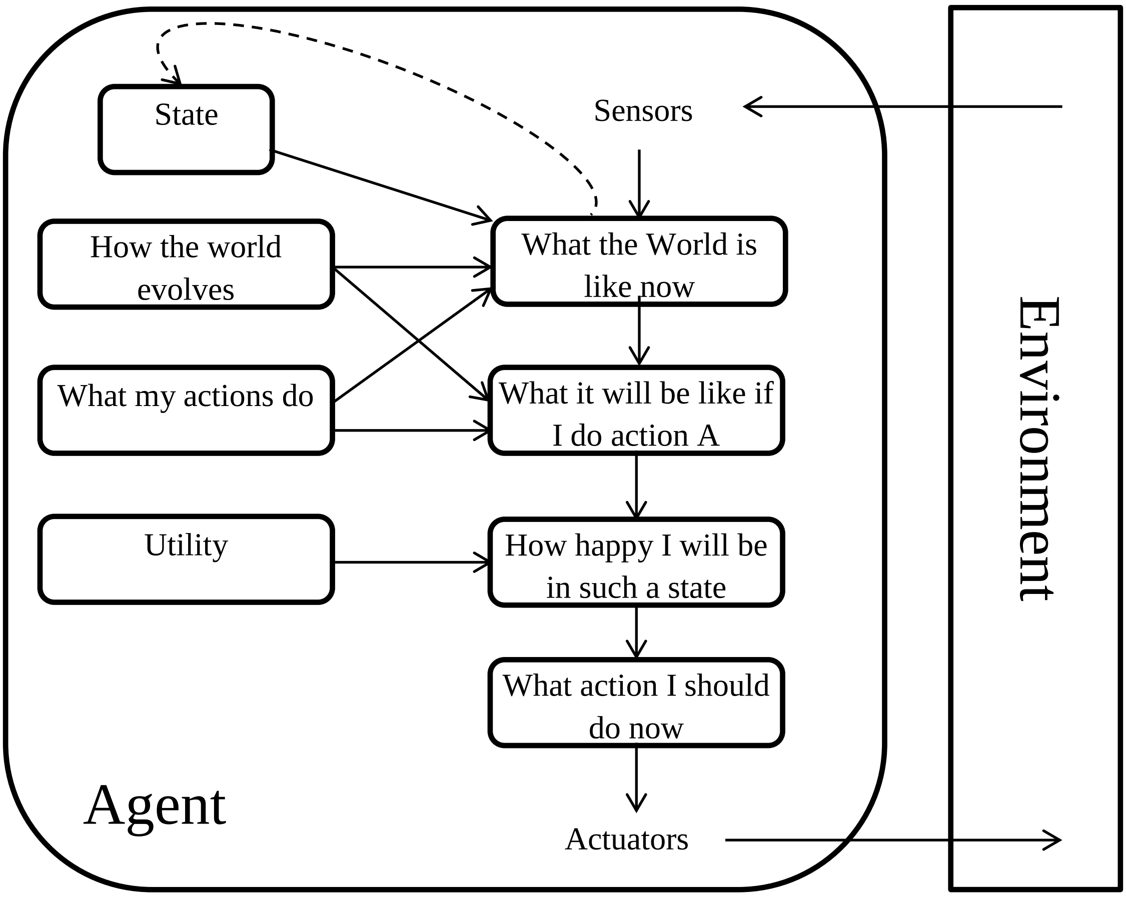

Figure 4.5 A model-based, utility-based agent. [165]

4.5.1.3 Architectures for Agents

The architecture that Wooldridge (2009) formalize at [147] is given below. Where E is set of environment, e, e' … are all possible configurations, Ac is set of actions, a, a', … are all possible actions, r is a run, e_0, e_l, e_2, … are state of environments, R = the set of all such possible finite sequences, R^{AC} = the subset of these that end with an action, R^E = the subset of these that end with an environment. Each action held by agent at (4.3) changes the environment. T = transformer function representing behaviour of environment.

$$E = \{e, e', ...\} \tag{4.6}$$

$$Ac = \{a, a', ... \} \tag{4.7}$$

$$r: e_0 \rightarrow e_l \rightarrow e_2 \rightarrow e_3 - . . . - \rightarrow e_u. \tag{4.8}$$

$$T: R^{AC} \rightarrow p(E) \tag{4.9}$$

By considering these, Environment (Env) is a triple where $e_0 \in E$ is an initial stage and Ag = agent function runs to actions, R^E = input from environment, Ac = Output as an action. Formally the sequence will be as (e_0, a_0, e_1, a_1, …) at (4.8)

$$Env = (E, e_0, T) \tag{4.10}$$

$$Ag = R^E \rightarrow Ac \tag{4.11}$$

$$R = (Ag, Env) \tag{4.12}$$

$$a_0=Ag(e_0) \tag{4.13}$$

For the next step there is a need for agents to execute some actions on behalf of its users. Utility function designed for an agent is an approach to achieve it. Minimum, maximum, average or sum of the utilities can be used in this context.

In the context of utility, there are also needs for option and filter functions. In options, according to current beliefs and intentions of an agent, it creates possible desires and options. Besides, in order to choose from these options, filter function is used to create new intention. Then agent adopts new beliefs from its environments. At 4.9 and 4.10, Bel = beliefs, Int = intentions and Des = desires.

$$Options: p(Be1) \times p(Int) \rightarrow p(Des) \tag{4.14}$$

$$Filter: p(Be1) \times p(Des) \times p(Int) \rightarrow p(Int) \tag{4.15}$$

Agents could depend on its opponents in some different ways. Independence, where there is no dependence between agents; unilateral, one depends on other while others do not; mutual, both agents depends on other agents [147]. In our study agents are mutually dependent with each other.

4.5.1.4 Interaction of Agents

As only one agent cannot execute any cooperation or negotiation, there is a need to have multi-agent environment to solve difficult problems that cannot be achieved without interaction of different stakeholders, in our case institutions. Figure 4.6 shows typical structure of multi-agent systems which suits to our study as well.

In multi-agent systems preference of agents were chosen according to their utility. Utility functions are the functions increasing the utility of an agent, not only monetary terms.

In order for agent to change its environment, state transformer function (T) is needed. Where Ac_i = Action of agent i, Ac_j = action of agent j and **Ω** = outcome of these actions.

$$T = Ac_i \times Ac_j \rightarrow \Omega \qquad (4.16)$$

In order to reach an agreement, mechanism should be designed which could be achieved by different properties, such as guaranteed success, maximizing social welfare, pareto efficiency, individual rationality, stability and simplicity [166].

In terms of negotiation between agents, there are different types of it, which are, one-to-one negotiation, many-to-one negotiation and many-to-many negotiations. Auctions could be seen as an example of many-to-one negotiation as auctioneer is one agent and bidders are many [147].

For interaction of agents, Seow and Sim (2008) proposed an agent-based model to allocate resources in efficient manner in a distributed environment [167]. In this study belief-desire-intention methodology was used. Belief of an agent was determined by question of agent i, whether there is any other resource (in our study activity) making me happier. If agent gets answer of yes, then it puts this activity belonging to agent j, into his/her mind. If the sum of next allocation is higher than the current one then desire set occurs. For the last, the maximum utility of desire set is called intention, as this way will be chosen. However, in that study the number of agents and the number of resources are the same [167], while in our study there are 3 agents with 59 activities.

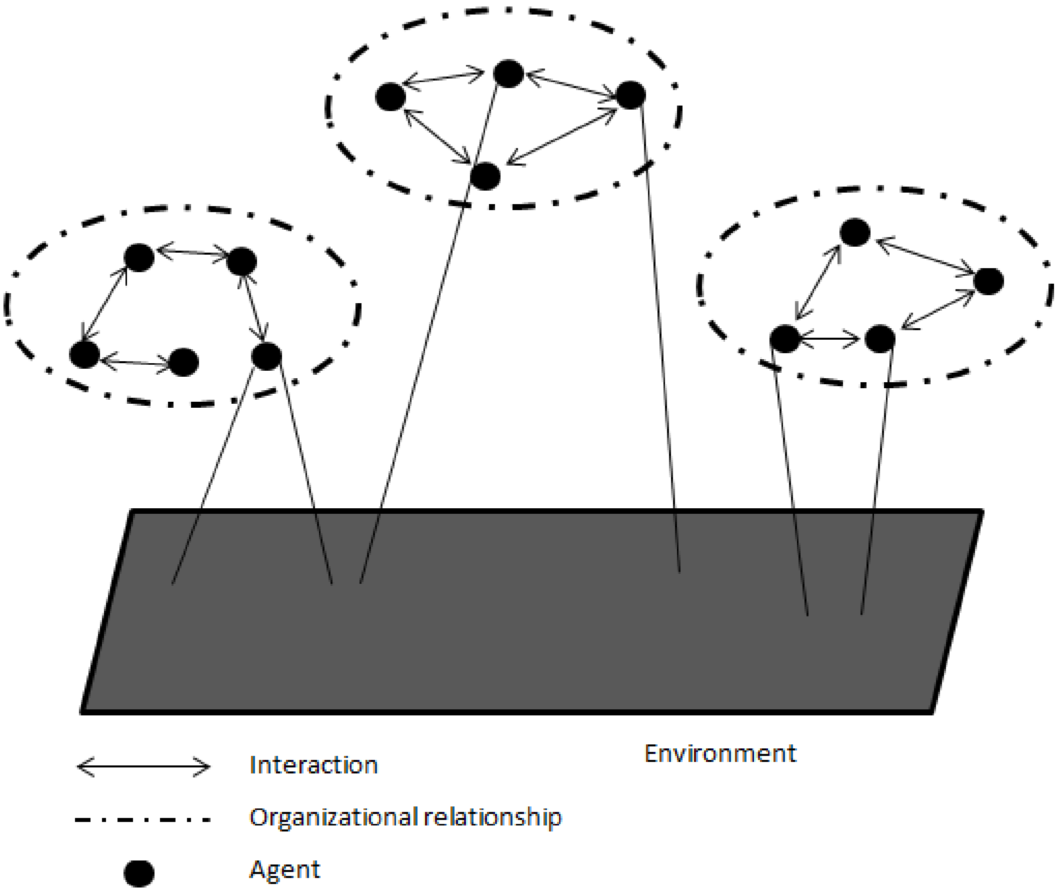

Figure 4.6 Typical structure of a multi-agent system [147]

4.5.1.5 Development of Multi Agent Environment

In order to generate a whole system, distributed problem solving proposed by Smith and Davis (1981) was adopted as it suits our method AHP, by giving hierarchical structure to decompose problems [168].

At figure 4.7, in problem decomposition phase the problem is divided to its components, which is the same as it has already been done in AHP process. In the second phase, which is sub-problem solution, activities are executed in order to solve the sub problems. In this phase, there is cooperation and sharing information among agents. At the last stage sub-solutions are integrated into one general solution [168].

Rosenschein and Zlotlun (1994) presented Task-Oriented Domain which is triple (T, Ag, c) [169]. While T= finite set of all possible tasks, Ag= (1,….,n) is finite set of agents, c: p(T) $\rightarrow$ IR^+ is function describing the cost of executing any set of tasks.

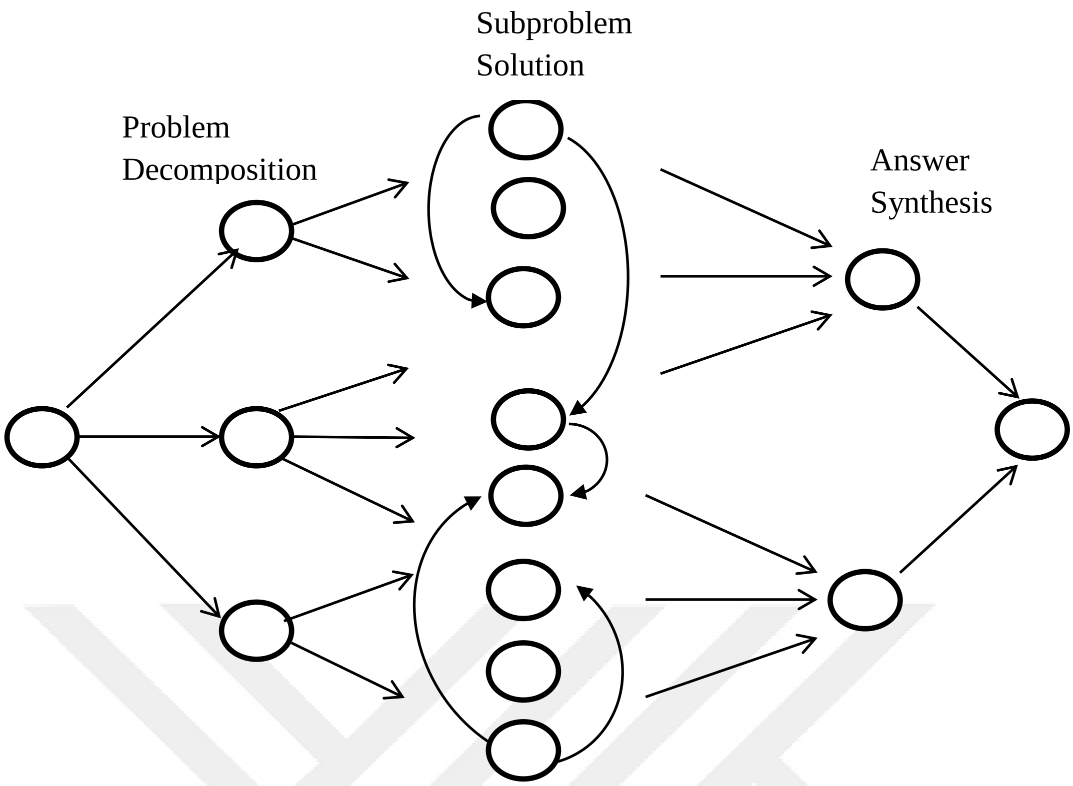

Figure 4.7 Phases of distributed problem solving [168]

Cost function has two main constraints, first it must be monotonic that adding more tasks never decrease the function; $T_{1,}\ T_2 \subset T$ and $T_1 \subset T_2 \rightarrow c(T_1) \leq c(T_2)$. Second constraint is doing nothing cost 0. In conflict each stakeholder, so-called agent have to perform all activities. $d=(D_{1,}D_2)$ is a deal. $cost_i(d)$= cost of deal to agent i, $c(T_i)$= cost of doing tasks without agreement, $Utility_i\,(d)$= utility of deal to agent i.

$$Utility_i\,(d) = c(T_i) - cost_i(d) \tag{4.17}$$

Endriss (2006) addresses that there are 7 interpretation of the term concession at [170];

(1) Strong concession: Make an offer which is better for every agent,

(2) Weak concession: Make an offer which is better for at least one of the other agents in the environment,

(3) Pareto concession: Make an offer which is at least as good as the prior one for all of the other agents and better for at least one of the agents,

(4) Utilitarian concession: Make an offer in which the sum of utilities of the other agents increases (it is also known as utilitarian social welfare),

(5) Egalitarian concession: Make an offer in which the minimum utility of all the other agents increases (it is known as egalitarian social welfare),

(6) Nash concession: Make an offer increasing the product of utilities of the other agents in the environment (Nash product),

(7) Egocentric concession: Make an offer which is not as good as the previous one for you.

From the light of above, it can be said that (1) was tried to be achieved in this study which suits best for disaster management from the perspective of institutions, because in this problem both social and individual welfare is important.

In terms of task allocation, Scerri et al. at [171] addresses four main constraints to tackle which are;

- Dynamic environment may cause tasks to appear and disappear,
- Agents could perform tasks at the same time even though there is a resource limit,
- Many agents have overlapping functionality to perform each task, but they have different levels of capability,
- Inter-task constraints may be presented.

Tran and Low (2008) addressed five main stages in multi-agent system processes at [172], [173] which are:

1) Analysis of the goal: Understanding the goal domain, analyzing the conflict of tasks and decomposing system task to small tasks which can be handled more easily.

2) Organization design: General structure of multi agent system is designed in this stage. It can be achieved by designing roles of each agent classes.

3) Internal activity design: It is related to respond mechanism of agents for internal and external events. If then rules are used in this stage

4) Agent interaction design: In this stage, solving mechanism of all possible conflicts is designed.

5) Architecture design: perception of agents' characteristics, effect of them and data flowing from environment to agents are designed.

4.5.2 Implementing MAS into Flood Risk Management

In the proposed model, agents, strategies and limits of agents, steps in the model and negotiation protocols were determined. In the modeling, Python 3 program was used. To test the codes that are used in Python, we solve the problem by hand as if there are only 9 actions.

4.5.2.1 Agents in the Model

Action plans, in other words interventions so as to decrease risks were determined to be allocated to the responsible institutions. The responsible organizations are not working integrated or separated purely. In real life example, from the light of action plans and flood factors, the responsible organizations are listed below:

- Water and sewerage administration,
- State hydraulic works,
- Local municipalities, authorities,
- Prime ministry disaster and emergency management presidency,
- Disaster coordination center,
- Search and rescue coordination center,
- The ministry of education; health; environment and urbanization; agriculture and forestry; labor, social policies and family; transportation and infrastructure; energy and natural resources; interior,
- Non-governmental organizations (NGO),
- Insurance companies,
- Building occupants

In case of disastrous events, all these stakeholders have an impact on the results or destructiveness of flooding. However the responsibilities are most of time clear and each responsible institution actually knows what to do. As it has already been mentioned at [181], there are mainly three stakeholders included in FRM systems which are; 1) water industry working for water supply, sewage and treatment systems, 2) local authorities responsible for roads and gully drainage; 3) EA (Environmental Agency) responsible for river management.

Moreover, full participation of the entire stakeholder is needed to determine actions, in more general flood management strategies [76]. However, Thaler and Levin-Keitel (2016) addresses that flood risk management (FRM) is considered by a high level of local self-responsibility in the context of planning and decision-making process. Stakeholder engagement in FRM most of time results in variety of discussions and conflicts between political leaders and stakeholders [174]. The lack is that, in built environment in terms of social, economic and environmental aspects, how much an institution focuses on each of these aspects with respects to reduce related risk [84]. It was addressed at [174] that there is a need to create grassroots organizations with social and economic structures apart from environmental ones. As resources are limited, in order to prioritize the tasks, the results of AHP were used. To complete tasks in proposed model, three agents with their ability to protect social, economic and environmental welfare were created, which is a novel approach for disaster management. In order to have sustainable solution to flood disaster management, three dimension of sustainability were used. All of the three agents have some focus on each of the three sustainable features but having more capability to make better one of them.

4.5.2.2 Proposed Model, Step by Step

Steps in the proposed model are listed below:

1) Determination of the flood mitigation measures related with each factor: By determining all the actions, each factor have some association with some of these actions. Some factors contain only one action while others contain more than one. This will result in all the bonds between factors and actions, so that the utilities of the actions can be calculated. Table 4.17 shows the relationship between factors and actions. At the table weights column shows the weights of each sub factors, sum of which equals to 1. These weights will be distributed to the corresponding actions according to data given by users.

2) Determination of the round of actions: As some actions take more time, cost and effort, there is a need to determine the round of each action so that the scheduling of them could be possible. Because determination of each task's duration or cost is very difficult [149], in this study we determine 5 type of action period. These rounds are not

only about timely manner, but it has also association with cost and effort that is needed. The rounds of each of them can be seen at Table 4.15.

3) Determination of the actions associated with more than one parameter: Some actions could be related to more than one parameter resulting in the overall utility from two parameters. In order to determine the utility of each of the actions, these actions should be determined.

Table 4.17 Actions depending on each factor

Main factors	**ID**	**Weights**	**Actions depending on each factors**
Institutional capacity	I1	0,023135	B47, B22
	I2	0,032036	B56, B37
	I3	0,057874	B55, B38, B34, B29, B13, B12, B10, B9
	I4	0,01749	B24
	I5	0,011643	B35
	I6	0,019214	B11, B27
Urban Infrastructure	U1	0,178258	B39, B57, B23, B4, B3, B2
	U2	0,086651	B39, B33, B28, B5, B1
	U3	0,024917	B39, B6
	U4	0,028854	B39, B7
	U5	0,017818	B39, B8
Land use	L1	0,054037	B22, B17, B15, B14, B25
	L2	0,021241	B22, B17, B15, B14, B26
	L3	0,027766	B22, B17, B15, B14, B20, B44
	L4	0,017595	B22, B17, B15, B14, B30
	L5	0,05376	B22, B17, B15, B14, B45
	L6	0,032744	B41
	L7	0,059721	B40, B43, B42, B46

Table 4.17 Actions depending on each factor (cont'd)

Superstructure capacity	S1	0,014034	B47
	S2	0,016406	B48
	S3	0,010562	B39, B59
	S4	0,01513	B49
	S5	0,026125	B50
	S6	0,008418	B31
	S7	0,011835	B39, B58
	S8	0,014942	B36
Demographic and social	D1	0,008085	B51, B18
	D2	0,009397	B56, B21, B37
	D3	0,01079	B52
	D4	0,017843	B53
	D5	0,023985	B19
Environmental	E1	0,019006	B20, B57
	E2	0,01502	B17, B15, B16
	E3	0,008665	B54
	E4	0,005004	B32

4) Data from institutions for current risk condition of actions: It can be said that some actions have already done or partly done while others has not been held before. To solve this problematic, user is asked to weight the current risk condition (c) of each of the actions. It should be between 1 and 0, while inner indicates very high risk of the action, latter indicates there is nothing left to do. High risk corresponds there has been nearly nothing done before. The possible answers and their impacts can be seen at Table 4.18.

5) Data from institutions for importance of actions: Some actions could have difference between whether the current condition of them is good or bad while others have no difference.

Table 4.18 Current level of actions

Question:	What is the current level of this action, in other words, what is the level of risk being created if action is not done?
Answer	**Meaning**
1	Very high risk- There has been nothing done before
0,75	High risk - There has only little been done before
0,5	Medium risk - There has something done before but requires improvement
0,25	Low risk - There has lots of effort been given to this action before, but still there is some efforts
0	Zero risk - There has been everything done before and There cannot be done anything else

These inquiry is actually similar to AHP process but in very basic way. There is only one question of two alternatives. Alternatives in this section are; action is in very good condition and action is in very bad condition. In other words, what would the change in output be if the input changes. These two alternatives are compared with each other and they are weighted. When good gets 1 and bad gets 0, it means that there is an extremely strong difference if the current condition of the activity is good or bad. When good gets 0.5, which is the least point of it, and bad gets inevitably 0.5, it means there is no any difference if this action is held or not. This process is also known as fuzzy preference relation addressed at [175]. To make it easier for respondents we just want them to fill good point between 1 and 0.5.Table 4.19 shows the meanings of numbers briefly.

6) Data from institutions related to social, economic and environmental weights of the actions ($E_{t,sos}$, $E_{t,eco}$, $E_{t,env}$): as the core of the study is determining the effect of flooding on built environment in terms of social, economic and environmental context, user is asked to weight each action in term of social, economic and environmental consequences or contributions. Then idealized weights of each actions upon economic, social and environmental ($E_{t,n,sos}$, $E_{t,n,eco}$, $E_{t,n,env}$) is calculated:

Table 4.19 Effect of the change in level of action

Question	How would the area's durability change if this action is held, what are the weights of good and bad conditions of the action on flood destructiveness?		
Good	**Bad**	**Distance**	**Meaning**
1	0	1	Extreme difference
0,9	0,1	0,8	Very high difference
0,8	0,2	0,6	High difference
0,7	0,3	0,4	Moderate difference
0,6	0,4	0,2	Little difference
0,5	0,5	0	No any difference

$$\mathrm{E}_{\mathrm{t,n,sos}} = \frac{\mathrm{E}_{\mathrm{t,sos}}}{\max_{\mathrm{E}_{\mathrm{t,sos}},\mathrm{E}_{\mathrm{t,eco}},\mathrm{E}_{\mathrm{t,env}} \in E_t} \; E_t} \tag{4.18}$$

$$\mathrm{E}_{\mathrm{t,n,eco}} = \frac{\mathrm{E}_{\mathrm{t,eco}}}{\max_{\mathrm{E}_{\mathrm{t,sos}},\mathrm{E}_{\mathrm{t,eco}},\mathrm{E}_{\mathrm{t,env}} \in E_t} \; E_t} \tag{4.19}$$

$$\mathrm{E}_{\mathrm{t,n,env}} = \frac{\mathrm{E}_{\mathrm{t,env}}}{\max_{\mathrm{E}_{\mathrm{t,sos}},\mathrm{E}_{\mathrm{t,eco}},\mathrm{E}_{\mathrm{t,env}} \in E_t} \; E_t} \tag{4.20}$$

7) Determination of agents' characteristics (Ag_t): for agent 1,2 and 3 called Ag1, Ag2 and Ag3 there is a need to determine agents preferences in terms of social, economic and environmental context. This can be changed by user, or draft can be used too. Then idealized weights of them are used for their preferences, as it can be seen at Table 4.20.

Table 4.20 Preferences of agents over built environment

Agents	**Normal weights**			**Idealized weights**		
	Social	Economic	Environment	Social	Economic	Environment
A1	0,5	0,25	0,25	1	0,5	0,5
A2	0,25	0,5	0,25	0,5	1	0,5
A3	0,25	0,25	0,5	0,5	0,5	1

8) Calculation of unit and total utility of actions:

$$\sum w_i = 1 \tag{4.21}$$

$$w_{a_i} = \frac{w_i d_{a_i}}{\sum_{a=1}^{n} d_{a_i}} \tag{4.22}$$

$$Total_{u_{a_i}} = c.w_{a_i} \tag{4.23}$$

$$t_a = c.t \tag{4.24}$$

Where i = 1,2, … m are the parameters, a = 1,2, … n are the actions related to parameters i, w_i is the relative weight of parameter i.

Where g_{a_i} and b_{a_i} are good condition and bad condition weights taken from user for action a and parameter i, d_{a_i} is the distance between them $(g_{a_i} - b_{a_i})$, w_{a_i} is the relative weight of action a in parameter i.

So for each parameter i, $\sum w_{a_i} = w_i$ and $\sum_{i=1}^{m}\sum_{a=1}^{n} w_{a_i} = 1$. c = current weight of an action taken from user, t is the time (round) assumed for an action, t_a real time that will be last of action a, and $Total_{u_{a_i}}$ is the total utility of an action a related to parameter i. If each c equals to 1 reflecting very high risk of flood related to this action and nothing have done before, $Total_{u_{a_i}}$equals to sum of w_i which is actually 1.

$$Total_u = \sum_{i=1}^{m}\sum_{a=1}^{n} Total_{u_{a_i}} \tag{4.25}$$

$$w_{t_{a_i}} = \frac{Total_{u_{a_i}}}{Total_u} \tag{4.26}$$

Where $Total_u$ = total utilities of each actions of each parameters and $w_{t_{a_i}}$= the weight of the total utility of action a in parameter i. So that $\sum w_{u_{a_i}} = 1$. For the calculation of the total utility that will be count in the game;

$$U_{a_i} = \frac{w_{t_{a_i}}}{t_a} \tag{4.27}$$

Where U_{a_i} is the unit utility of an action a in parameter i.

So far, we are still in the base of parameters because some actions are held by more than 1 parameter. In order to become purely actions to put them in the agent environment:

$$U_a = \sum_{i=1}^{m} U_{a_i} \tag{4.28}$$

$$K_a = U_a t_a \tag{4.29}$$

Where $U_a =$ the unit utility of action a, and $K_a =$ the total utility of action a. It is also relative weights, it means that total utility at the end of the game could be 1 but it is too utopic. It can be said that for actions which are related to only one parameter, U_a = U_{a_i} as there is only for one parameter i there are some utilities.

It is known that $\sum_{a=1}^{n} U_a\, t_a = 1$

$$P_a = 0.05K_a \tag{4.30}$$

9) Determination of agents' priorities and aims upon actions: By acquiring 7) and 8), agents' priority vectors were determined according to agents' and actions' weights upon social, environmental and economic welfare, from matrix multiplication:

$$A_{km} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{k1} & \cdots & x_{km} \end{bmatrix} \; and \; B_{mn} = \begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{bmatrix} \tag{4.31}$$

$$Z_{kn} = A_{km} \; x \; B_{mn} \tag{4.32}$$

Where k is the number of agent, m is the number of type which is 3 in our case as social, economic and environmental, and n is the number of actions. The idealized form of each column of the matrix Z_{kn} = N_{Ag_a} so that agents priorities are achieved. In the future calculations, ideal elements were used (N_{Ag_a}). Each agent is firstly assigned to the actions where their idealized weights are 1. Then the aim of the each agent in terms of utility is calculated as:

$$H_{Ag} = \begin{Bmatrix} \sum_{a=1}^{m} K_a, & if \; N_{Ag_a} = 1 \\ 0, & else \end{Bmatrix} \tag{4.33}$$

Where N_{Ag_a}= Idealized value of preference of the agent Ag to action a, and H_{Ag}= the aim of agent Ag for overall, which are also relative weights as $H_{Ag1} + H_{Ag2} + H_{Ag3} + \cdots + H_{Agk} = 1$ and k is the number of agent.

10) Solving the problem of slacking: as we do not want any agent to wait others to do activities in their objectives every time, in other words, time is also an important parameter, time penalty is implemented in the model. After all actions are held the minimum execution time is regarded as aimed time. Each round delay is rewarded as some decrease in utility general, which is distributed to all the agents according to their utilities U_{Ag}= Utility of Ag as a result of the sum of K_a denoted to agent Ag. The formulations are listed below:

$$T_{delay} = \max_{Ag \in AG} T_{Ag,E} - \frac{\sum t_a}{k} = T_{actual} - T_{opt} \tag{4.34}$$

$$T_{distance} = T_{worst} - T_{opt} \tag{4.35}$$

$$P_t = \frac{T_{actual} - T_{opt}}{(T_{worst} - T_{opt})} = \frac{T_{delay}}{(T_{distance})} \tag{4.36}$$

Where T_{delay} is delay time of the project, $T_{Ag,E}$ = Total duration of set of action E done by agent Ag, $\max_{Ag \in AG} T_{Ag,E}$ is the actual time of the project, AG is a set of agents. k is the number of agents and the best time of the project (T_{opt}) is undoubtedly averagely distributed of times to agents. $T_{distance}$ indicates the possible worst case. P_t indicates the total time penalty which will be distributed to agents. $P_{t,Ag}$ is the time penalty of agent Ag.

$$U_{r,Ag} = U_{Ag} - P_{t,Ag} \tag{4.37}$$

$$U = \sum_{Ag=1}^{k} U_{r,Ag} \tag{4.38}$$

Where $U_{r,Ag}$= real utility of agent Ag, U = total utility regardless of time and deformity.

11) Deformity: If agents are not closed to their objectives they become nervous having more intervention possibility of other agents' ongoing actions. As a result of a process, the difference between their objective and reward, if they are not above the reward, is called as "deformity". If they are above their objectives then deformity equals to 0.

As each action is assigned to agents, total utility of the system is calculated as:

$$De_{Ag,s} = \begin{cases} \sum 1 - \frac{U_{Ag}}{H_{Ag}} & if\ H_{Ag} > U_{Ag} \\ 0 & else \end{cases} \tag{4.39}$$

$$De_{Ave} = \frac{\sum_{Ag=1}^{k} De_{Ag}}{k} \tag{4.40}$$

$$U_r = \sum_{Ag=1}^{k} U_{r,Ag} \tag{4.41}$$

$$U_{Net,Ag} = U_{r,Ag} - De_{Ag} \tag{4.42}$$

$$U_{Net} = U_r - De_{Ave} = \sum U_{Net,Ag} \tag{4.43}$$

Where $De_{Ag,s}$= deformity that agent Ag put to the system, De_{Ave}= average deformity of agents. Then De_{Ave} will be distributed to agents according to their utilitiesU_{Ag}. For each agent it will beDe_{Ag}. This makes agents to be penalized because of other agents as well as itself. U_r = total utility of agents regardless of deformities and U_{Net}= net utility of the proposed multi agent system that agents want it to maximize. General mechanism of these steps can be seen at Figure 4.7.

4.5.2.3 Strategies and limits of Agents

Agents start with their optimal proposals, gathered by an allocation agent. In each subsequent round, in other words each change in environment, an agent has to answer the question of, "should I make a concession?" [170].

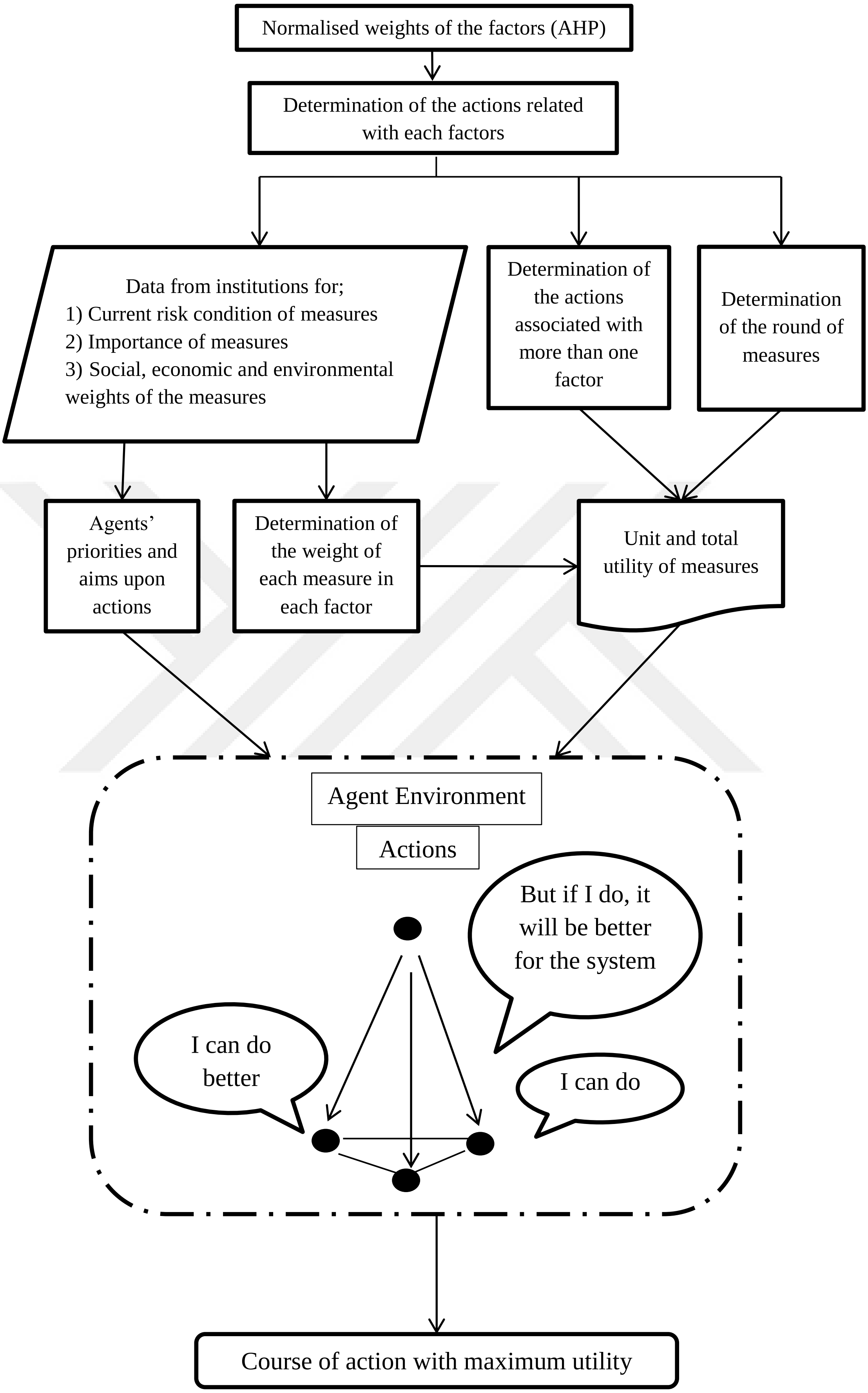

Figure 4.8 General mechanisms of data collection for MAS

As the reward is the same in any case minimizing cost makes the task allocation feasible. Rounds as a time reflects the cost of an activity, in general cost of disaster preparedness, response and rehabilitation. Rules of the games in this study are listed below:

1) Agents start the game according to their starting negotiation protocols and continue with the same strategy.

2) Agent i can recall some actions being taken by another agent called j only if agent i have more capability than agent j.

3) If an agent i recall the activity a_1 then the total utility of this action decrease by 5% as a decrease of effectiveness because of dual intervention of the action. Then agent j, whose activity a_1 is taken by agent i, seeks to find another action.

4) If activities, that are in the objective of agent i finishes, then “do nothing” option emerges.

5) Agents are focused on unit utility then total utility, so they might be willing to seek actions with shorter duration, then that of longer duration even though the total utility of longer action is higher than the shorter ones.

6) Each time lag as a round will result in some utility loss, distributed to each agent according to their utility (4.36).

7) If unit utilities of two actions are the same then one with longer duration is appeal to agents.

8) Agents do not regret, so if they do not choose to take some actions from other agents, they will never think of it for the same actions.

9) Renege is not allowed, so that agents cannot stop actions that they have already started.

10) Action that has already been interfered cannot be interfered one more time. It means that each activity intervention can happen only once.

In the following part, strategies of agents will be addressed.

4.5.3 Negotiation Protocols

In the study some negotiation protocols were used for agents to interact with each other and increase their utilities. Negotiations become critical when an agent want to execute an action and to interfere with activity which has already started by other agent, however with lower capability. Agents' strategies were divided into two main categories which are strategies for starting an activity and strategies for interfering others' task or not. In general, the game has four types of strategy which are; passive, greedy, passive-greedy and coward. In greedy and passive-greedy approaches, they then go to greedy strategies, in other words the strategies for intervention of others' actions. These will be called as greedy-greedy, greedy-social welfare, greedy-objective and greedy-zeuthen-based.

When the modeling is held, belief-desire-intention (BDI) methodology and motion at [147] was adopted. Greedy [176], social welfare [177], objective [178], Zeuthen-based [179], [180] and coward [181] algorithms were used in the model. The algorithms of totally 13 strategies will be given in the following part.

4.5.3.1 Passive algorithm (p-p)

In passive strategy, without considering time penalty, agents are willing to execute tasks in their objectives in the order of actions' contribution to agent's utility. If agents are passive, there is no intervention in the game. Agents start with actions having the highest utility. Unit utility of action a to agent i is:

$$U_{i_a} = e_{u_u}\, x\, q_{i_e} \tag{4.44}$$

Where e_{u_u} = unit utility of action e and, q_{i_e} = capability of agent i over action e. agents starts with actions, and each step round becomes round – 1, when the round of one action belongs to agent finishes, in other words becomes 0, it seeks to find a new action. The algorithm is:

1) For agent i whose round = 0

    For each e ∈ E

        If q_i = 1

            argmax$_{e\,\in E}$ $e_{u_u} q_{i_e}$= e

        Agent i hold action e, E= E – e, go to 1)

It means, each agent only holds actions if their capability = 1 and it hold these actions at the sequence of priorities of their unit utilities.

4.5.3.2 Passive direct algorithm (p-d)

In this strategy, agents start with actions giving maximum utility to single one of them. After all, when any of the agents' activity ends, it takes the remaining activity with maximum utility. Each round it goes like that. It can be seen as an alternative to passive strategy as it decreases time loss, as well as utility regardless of time loss. It, however, increases deformity losses enormously. As it is not known that which will create more utility overall, this strategy is adopted by our study.

4.5.3.3 Coward algorithm (p-c)

In coward strategy, agents are not only looking at the actions that their corresponding q values are 1. All actions are in their interest. However, when they want to hold actions with different q values than 1, which means there is another agent who may want to hold this action, they check if it is possible for other agent to want this action within the time of e. So the algorithm will be at the following:

1) For agent i whose round = 0

2) For each e ∈ E

argmax$_{e \in E}\, e_{u_u} q_{i_e}$ = e

If $q_{i_e} \geq q_{j_e}, q_{k_e}$ then:

i holds e, go to 1)

Elif $q_{j_e} > q_{i_e} \geq q_{k_e}$ then:

If $e_{j_{rem,r}} \geq e_r$ then i holds e go to 1)

Else: go to 2), E = E - e

Elif $q_{j_e}, q_{k_e} > q_{i_e}$ then:

If $e_{j_{rem,r}}, e_{k_{rem,r}} \geq e_r$ then i holds e go to 1)

Else: go to 2), E = E – e

There are 2 more coward strategies named coward Zeuthen based (p-c-z) and coward objective (p-c-o). In these strategies agents are checking their risks and distance to objectives respectively. In addition to coward strategy, if the risk or objective limits are worse for agents, then they hold corresponding actions.

4.5.3.4 Greedy-Greedy algorithm (g-g)

In greedy strategy, agents check the actions, if the chosen action is being held by another agent, the agent check the intervention penalty. If this penalty does not change the desire of the agent, it takes action e from agent j as this action gives maximum utility. penalty is calculated by the following equation:

$$U_{i_e} = e_{u_u}\, x\, q_{i_e} - \frac{(\, e_r\, x\, e_{u_u}\, x\, P_a)}{e_{j_{rem,r}}} = \text{A} \tag{4.45}$$

It means there is a P_a% penalty of the total utility of action e, if agent i want to hold this action from another agent. By having pilot studies, P_a=0.05 were determined. This penalty will be distributed to remaining rounds equally. This equation will be used in any greedy approaches. The algorithm of the greedy-greedy strategy is:

1) For agent i whose round = 0

2) For each e ∈ E

argmax$_{e\,\in E}$ $e_{u_u} q_{i_e}$= e

3) If e is hold by another agent j

If $q_{i_e} > q_{j_e}$ then:

If $\max_e(\max_{e\,\in E-e} e_{u_u} q_{i_e},\ \ A) = A$ then:

Agent i hold action e from agent j,

Unit utility of agent i = A, go to 1)

Else: go to 2), E = E - e

Else: go to 2), E = E - e

Else: agent i holds action e, unit utility = $e_{u_u}\, x\, q_{i_e}$, go to 1)

4.5.3.5 Greedy-Social Welfare algorithm (g-s)

In social welfare algorithm, agent I starts the same as greedy-greedy strategy, then it deepen and ask himself that how much I could make profit and loss to whole system. Then it outweighs the loss and profit, if profit is higher, then it chose the option of intervention.

For agent i whose round = 0

1) For each e ∈ E

   argmax$_{e \in E}$ $e_{u_u} q_{i_e}$ = e

2) If e is hold by another agent j:

   If $q_{i_e} > q_{j_e}$ then:

      If max$_e$(max$_{e \in E-e}$ $e_{u_u} q_{i_e}$, $A) = A$ then:

         Total profit = $e_{j_{rem,r}}$ x e_{u_u} x $(q_{i_e} - q_{j_e})$

         Total loss= e_r x e_{u_u} x 0.05

            If total profit > total loss then:

               Agent i holds action e from agent j, unit utility = A

               Go to 1), it must be agent j

            Else: go to 2), E = E - e

      Else: go to 2), E = E - e

   Else: go to 2), E = E - e

Else: agent i holds action e, unit utility = e_{u_u} x q_{i_e}, go to 1)

4.5.3.6 Greedy-Objective algorithm (g-o)

In objective algorithm, agent i starts the same as greedy-greedy strategy, then it starts thinking of itself and its opponent. It asks how far am I to my target and how far is my opponent to its target. Then it outweighs the distances of both agent i and j, if distance of i is more than j, it choose the option of intervention. The algorithm is:

1) For each $e \in E$

$\text{argmax}_{e \in E}\, e_{u_u} q_{i_e}$ = e

2) If e is hold by another agent j:

If $q_{i_e} > q_{j_e}$ then:

If $\max_e(\max_{e \in E-e} e_{u_u} q_{i_e}, \quad A) = A$ then:

$H_{i,j}$ = target of agent i and j

$Z_{i,j}$ = the utility of each agent up until now.

Total loss= $e_r\ x\ e_{u_u}\ x\ 0{,}05$

If $H_i - Z_i > H_j - Z_j$ then:

Agent i holds action e from agent j, unit utility = A

Go to 1), it must be agent j.

Else: go to 2), E = E - e

Else: go to 2), E = E - e

Else: go to 2), E = E - e

Else: agent i holds action e, unit utility = $e_{u_u}\ x\ q_{i_e}$, go to 1)

4.5.3.7 Greedy-Zeuthen-Based algorithm (g-z)

In Zeuthen-based algorithm, agent i starts the same as greedy-greedy strategy, then it starts thinking of itself and its opponent too. However in this strategy it asks how much risk will I have subjected to if I do not choose the intervention, and how much risk does my opponent have if I choose intervention. Then it outweighs the risks of both itself and agent j. If risk of i is more than j, it choose the option of intervention. Otherwise it seeks another action, having second highest utility. The algorithm is:

1) For each e ∈ E

argmax$_{e \in E}\, e_{u_u} q_{i_e}$= e

2) If e is hold by another agent j:

If $q_{i_e} > q_{j_e}$ then:

If $\max_e(\max_{e \in E-e} e_{u_u} q_{i_e}, \quad A) = A$ then:

Go to 2), check what would agent i do if there is no e (e2)

Go to 2), check what would agent j do if there is no e (e3)

$\text{Risk}_\text{i} = \frac{A-(q_{i_{e2}}\ x\ e2_{u_u})}{A}$

$\text{Risk}_\text{j} = \frac{(q_{j_e}\ x\ e2_{u_u})-(q_{j_{e3}}\ x\ e3_{u_u})}{(q_{j_e}\ x\ e2_{u_u})}$

If $\text{Risk}_\text{i} > \text{Risk}_\text{j}$ then:

Agent i holds action e from agent j, unit utility = A

Go to 1), it must be agent j.

Else: go to 2), E = E - e

Else: go to 2), E = E - e

Else: go to 2), E = E - e

Else: agent i holds action e, unit utility = $e_{u_u}\ x\ q_{i_e}$, go to 1)

4.5.3.8 Passive-Greedy algorithm

In passive greedy algorithms, agents start their preferences same as passive strategy but then, when any of them cannot find any action whose q value equals to 1, then all agents become greedy, choosing greedy strategy. The name and notation of these strategies are: passive greedy greedy (p-g-g), passive greedy objective (p-g-o), passive greedy zeuthen based (p-g-z) and passive greedy social welfare (p-g-s). It will let us not to wait too much in strongly asymmetric distribution of actions and targets to agents.

All strategies in this study can be seen at Figure 4.8. Figure 4.9 also shows the general mechanism of the agent environment

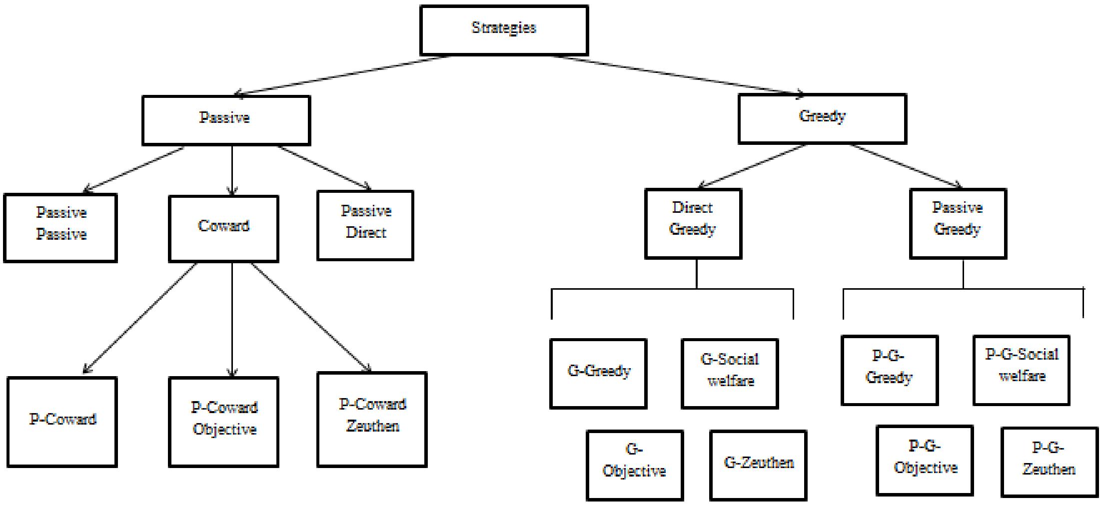

Figure 4.9 Strategies in the study

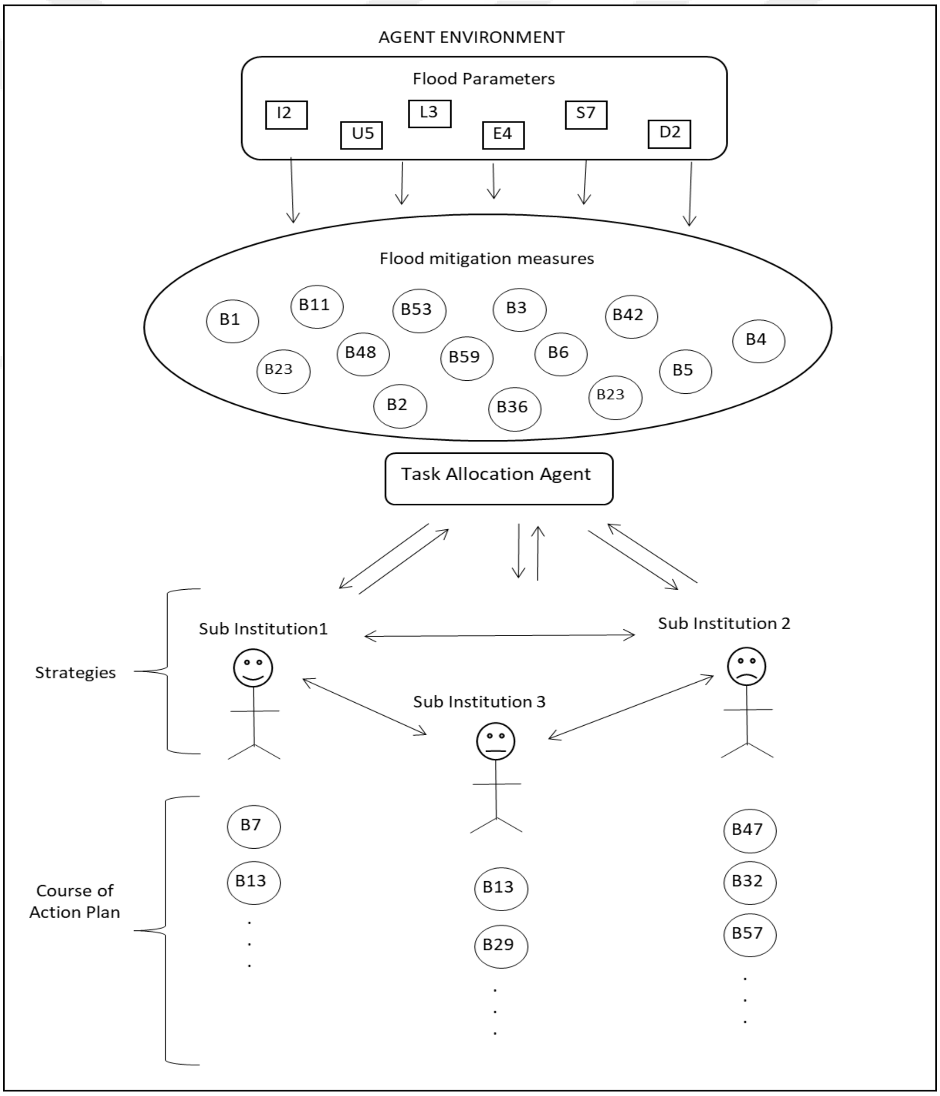

Figure 4.10 Agent environment in the study

CHAPTER 5

ILLUSTRATIVE CASE STUDY

In this chapter, findings of MAS processes will be illustrated. To run the proposed model developed in Python 3 environment, a district in Turkey was choosen. Questions were asked to 2 municipality specialists of the district, and gathered data were written in Microsoft Excel program. These data were read in Python 3 program to run the process. The findings will be focused in terms of the number of 13 strategies with interaction of 3 agents namely social-based, economic-based and environmental-based.

5.1 Data Taken from the Municipality

The data taken from the municipality in terms of current condition, importance of action, and socio-economic-environmental preferences are shown at Table 5.1. As it can be seen B9, B10, B11, B14 and B55 will not be used in the model as there is no any risk for first four of them and there is no need of action named B55 in terms of its importance.

5.2 Allocation of Disaster Mitigation Measures

Multi agent system is modeled in Python 3 program by using mainly numpy and pandas libraries with the number of 13 strategies. To test model, a district in Turkey is choosen.

5.2.1 Utility and Capability of Each Agent Over Actions

54 of the actions out of 59 were determined to have power to decrease flood risk according to answers of the experts. It was observed that, agents have strong desire to hold actions named B3, B15 and B5 when considering all of the greedy strategies.

Table 5.1 Actions and their conditions

Code	**Current condition (0-1)**	**Good (0,5-1)**	**Bad**	**Soc.**	**Eco**	**Env.**
B1	0,1	0,51	0,49	0,4	0,5	0,1
B2	0,5	0,55	0,45	0,6	0,3	0,1
B3	0,9	1	0	0,3	0,4	0,3
B4	0,8	1	0	0,3	0,4	0,3
B5	0,5	0,55	0,45	0,4	0,5	0,1
B6	0,3	0,55	0,45	0,8	0,2	0
B7	0,4	0,55	0,45	0,8	0,2	0
B8	0,1	0,51	0,49	0,8	0,2	0
B9	0	0,5	0,5	0,3	0,5	0,2
B10	0	0,5	0,5	0,5	0,3	0,2
B11	0	0,5	0,5	0,5	0,4	0,1
B12	0,1	0,6	0,4	0,3	0,3	0,4
B13	0,5	0,6	0,4	0,6	0,3	0,1
B14	0	0,85	0,15	0,3	0,2	0,5
B15	0,9	0,95	0,05	0,4	0	0,6
B16	0,1	0,58	0,42	0,2	0,1	0,7
B17	0,5	0,6	0,4	0,2	0	0,8
B18	0,3	0,7	0,3	0,5	0,5	0
B19	0,4	0,9	0,1	1	0	0
B20	0,2	0,55	0,45	0,2	0,1	0,7
B21	0,1	0,6	0,4	0,4	0,1	0,5
B22	0,8	0,8	0,2	0,5	0,3	0,2

Table 5.1 Actions and their conditions (cont'd)

B23	0,1	0,52	0,48	0,2	0,6	0,2
B24	1	1	0	0,8	0,2	0
B25	0,9	0,55	0,45	0,1	0,9	0
B26	0,8	0,6	0,4	0,1	0,9	0
B27	0,5	1	0	0,8	0,2	0
B28	0,1	0,52	0,48	0,6	0,4	0
B29	0,6	0,65	0,35	0,5	0,3	0,2
B30	0,2	0,52	0,48	0	0,8	0,2
B31	0,8	0,7	0,3	0,2	0,8	0
B32	1	0,8	0,2	0,1	0	0,9
B33	0,3	0,57	0,43	0,3	0,7	0
B34	0,5	0,6	0,4	0,3	0,6	0,1
B35	0,6	0,75	0,25	0,4	0,4	0,2
B36	0,9	0,72	0,28	0,3	0,7	0
B37	0,8	0,9	0,1	0,6	0,3	0,1
B38	0,5	0,9	0,1	0,2	0,3	0,5
B39	0,9	0,75	0,25	0,3	0,4	0,3
B40	0,1	0,51	0,49	0,8	0,2	0
B41	1	1	0	0,5	0,2	0,3
B42	0,6	0,65	0,35	0,8	0,2	0
B43	1	0,7	0,3	0,2	0	0,8
B44	0,1	0,58	0,42	0,6	0	0,4
B45	0,7	0,9	0,1	0,3	0,6	0,1
B46	0,2	0,6	0,4	0,7	0,3	0

Table 5.1 Actions and their conditions (cont'd)

B47	0,5	0,51	0,49	0,2	0,8	0
B48	0,7	0,8	0,2	0,2	0,8	0
B49	0,9	0,8	0,2	0,3	0,3	0,4
B50	1	0,9	0,1	0,5	0,4	0,1
B51	0,9	0,7	0,3	0,4	0,5	0,1
B52	0,9	0,85	0,15	1	0	0
B53	0,1	0,55	0,45	0,7	0	0,3
B54	1	0,53	0,47	0,2	0	0,8
B55	1	0,5	0,5	0,2	0,3	0,5
B56	0,9	0,95	0,05	0,6	0,3	0,1
B57	0,6	0,6	0,4	0,5	0,3	0,2
B58	0,5	0,52	0,48	0,4	0,3	0,3
B59	0,4	0,55	0,45	0,3	0,7	0

These actions are "Increase the maintenance of storm water drainage capacity", "Afforestation" and "Increase the maintenance of transportation network" respectively. It makes sense because these three actions are at the head of the unit utility rankings by 0.014728, 0.012930, and 0.007820 respectively, while the corresponding agents are economic, environmental and social ones. Even though in terms of total utility action B38, which is "Dredge, widen, remediate streams and channels", have the highest point, because its real duration equals to 225 round, at the highest round in this case, it was not appealed to any of the agents as unit utility is not as high as its total utility. In passive and passive greedy strategies, B3 and B15 is also appeals to two agents, however, social agent has selected B22, which is "Increase legal conditions and regulations about flood" instead of B5. The reason is that because capability of social agent over B5 is not 1, in other words, some other agents can do this action better than social agent. Unit and total utility of actions, capabilities of agents over these actions and unit utility of each agent over each action can be seen at Table 5.2. Agent 1 stands for social, Agent 2 stands for economic and Agent 3 represents environmental agents at the table.

Table 5.2 Utility and capability of agents

ID	**Utility of actions**		**Capability**			**Unit utility of agents**		
	Unit utility	Total utility	Agent 1	Agent 2	Agent 3	Agent 1	Agent 2	Agent 2
B1	0,00013	0,00026	0,9333	1,0000	0,7333	0,0001	0,0001	0,0001
B2	0,00147	0,00736	1,0000	0,8125	0,6875	0,0014	0,0012	0,0010
B3	0,01473	0,13255	0,9285	1,0000	0,9285	0,0136	0,0147	0,0136
B4	0,00147	0,11782	0,9285	1,0000	0,9285	0,0013	0,0014	0,0013
B5	0,00782	0,03910	0,9333	1,0000	0,7333	0,0073	0,0078	0,0057
B6	0,00017	0,00260	1,0000	0,6666	0,5555	0,0001	0,0001	0,0001
B7	0,00004	0,00150	1,0000	0,6666	0,5555	0,0000	0,0000	0,0000
B8	0,00001	0,00010	1,0000	0,6666	0,5555	0,0000	0,0000	0,0000
B12	0,00021	0,00213	0,9285	0,9285	1,0000	0,0002	0,0002	0,0002
B13	0,00107	0,01065	1,0000	0,8125	0,6875	0,0011	0,0009	0,0007
B15	0,01293	0,11637	0,8750	0,6250	1,0000	0,0113	0,0081	0,0129
B16	0,00022	0,00022	0,7059	0,6471	1,0000	0,0002	0,0001	0,0002
B17	0,00144	0,01437	0,6667	0,5556	1,0000	0,0010	0,0008	0,0014
B18	0,00016	0,00095	1,0000	1,0000	0,6667	0,0002	0,0002	0,0001
B19	0,00094	0,00375	1,0000	0,5000	0,5000	0,0010	0,0005	0,0005
B20	0,00037	0,00148	0,7059	0,6471	1,0000	0,0003	0,0002	0,0004
B21	0,00001	0,00012	0,9333	0,7333	1,0000	0,0000	0,0000	0,0000
B22	0,00477	0,07626	1,0000	0,8666	0,8000	0,0047	0,0041	0,0038
B23	0,00006	0,00059	0,7500	1,0000	0,7500	0,0000	0,0000	0,0000
B24	0,00034	0,00684	1,0000	0,6666	0,5555	0,0003	0,0002	0,0002
B25	0,00004	0,00380	0,5789	1,0000	0,5263	0,0000	0,0000	0,0000
B26	0,00003	0,00256	0,5789	1,0000	0,5263	0,0000	0,0000	0,0000
B27	0,00075	0,00751	1,0000	0,6666	0,5555	0,0007	0,0005	0,0004
B28	0,00005	0,00052	1,0000	0,8750	0,6250	0,0000	0,0000	0,0000
B29	0,00064	0,01917	1,0000	0,8666	0,8000	0,0006	0,0005	0,0005
B30	0,00001	0,00011	0,5555	1,0000	0,6666	0,0000	0,0000	0,0000

Table 5.2 Utility and capability of agents (cont’d)

B31	0,00016	0,00263	0,6666	1,0000	0,5555	0,0001	0,0001	0,0001
B32	0,00020	0,00196	0,5789	0,5263	1,0000	0,0001	0,000	0,0002
B33	0,00036	0,00547	0,7647	1,0000	0,5882	0,0002	0,0003	0,0002
B34	0,00213	0,01065	0,8125	1,0000	0,6875	0,0017	0,0021	0,0014
B35	0,00009	0,00273	1,0000	0,9858	0,8511	0,0001	0,0001	0,0001
B36	0,00029	0,00526	0,7647	1,0000	0,5882	0,0002	0,0003	0,0002
B37	0,00082	0,01315	1,0000	0,8125	0,6875	0,0008	0,0006	0,0005
B38	0,00034	0,04260	0,8000	0,8666	1,0000	0,0003	0,0003	0,0003
B39	0,00079	0,17712	0,9285	1,0000	0,9285	0,0007	0,0008	0,0007
B40	0,00002	0,00020	1,0000	0,6666	0,5555	0,0000	0,0000	0,0000
B41	0,00026	0,01281	1,0000	0,8000	0,8666	0,0002	0,0002	0,0002
B42	0,00030	0,01828	1,0000	0,6666	0,5555	0,0003	0,0002	0,0001
B43	0,00081	0,04062	0,6666	0,5555	1,0000	0,0005	0,0004	0,0008
B44	0,00008	0,00039	1,0000	0,6250	0,8750	0,0000	0,0000	0,0000
B45	0,00053	0,01840	0,8125	1,0000	0,6875	0,0004	0,0005	0,0003
B46	0,00041	0,00406	1,0000	0,7647	0,5882	0,0004	0,0003	0,0002
B47	0,00030	0,00304	0,6666	1,0000	0,5555	0,0002	0,0003	0,0002
B48	0,00032	0,00449	0,6666	1,0000	0,5555	0,0002	0,0003	0,0002
B49	0,00030	0,00533	0,9285	0,9285	1,0000	0,0003	0,0003	0,0003
B50	0,00051	0,01022	1,0000	0,9333	0,7333	0,0005	0,0004	0,0003
B51	0,00016	0,00285	0,9333	1,0000	0,7333	0,0001	0,0001	0,0001
B52	0,00042	0,00380	1,0000	0,5000	0,5000	0,0004	0,0002	0,0002
B53	0,00070	0,00070	1,0000	0,5882	0,7647	0,0007	0,0004	0,0005
B54	0,00034	0,00339	0,6666	0,5555	1,0000	0,0002	0,0001	0,0003
B56	0,00185	0,01664	1,0000	0,8125	0,6875	0,0018	0,0015	0,0012
B57	0,00039	0,02362	1,0000	0,8666	0,8000	0,0004	0,0003	0,0003
B58	0,00007	0,00034	1,0000	0,9285	0,9285	0,0001	0,0001	0,0001
B59	0,00007	0,00055	0,7647	1,0000	0,5882	0,0000	0,0000	0,0000

5.2.2 Objective of Each Agent

Actions for each agent executing it with highest capability and as a result the objective scores for agents can also be seen at Table 5.3. “Course of action plan” listed at Table 5.3 also shows the process of p-p strategy.

Table 5.3 Prior actions and objective scores for each agent

Social agent (Ag1)		**Economic agent (Ag2)**		**Env. agent (Ag3)**	
Action	Total utility	Action	Total utility	Action	Total utility
B2	0,0073640	B1	0,0002607	B12	0,0021302
B6	0,0025986	B3	0,1325520	B14	0,0000000
B7	0,0015046	B4	0,1178240	B15	0,1163720
B8	0,0001032	B5	0,0391005	B16	0,0002238
B10	0,0000000	B9	0,0000000	B17	0,0143669
B11	0,0000000	B23	0,0005891	B20	0,0014809
B13	0,0106509	B25	0,0038038	B21	0,0001161
B18	0,0009485	B26	0,0025559	B32	0,0019569
B19	0,0037520	B30	0,0001128	B38	0,0426034
B22	0,0762574	B31	0,0026338	B43	0,0406182
B24	0,0068399	B33	0,0054741	B49	0,0053252
B27	0,0075140	B34	0,0106509	B54	0,0033885
B28	0,0005213	B36	0,0052591	B55	0,0000000
B29	0,0191715	B39	0,1771212		
B35	0,0027319	B45	0,0183962		
B37	0,0131471	B47	0,0030361		
B40	0,0002031	B48	0,0044911		
B41	0,0128056	B51	0,0028456		

Table 5.3 Prior actions and objective scores for each agent (cont'd)

B42	0,0182782	B59	0,0005507	
B44	0,0003919			
B46	0,0040618			
B50	0,0102171			
B52	0,0037978			
B53	0,0006978			
B56	0,0166393			
B57	0,0236199			
B58	0,0003428			
Objective scores:	**0,2441602**	**0,5272577**		**0,2285822**

From the light of unit utility of each action to each agent, agent environment were created as shown at Figure 4.9. Then strategies were applied to agent environment as a multi agent negotiation process.

5.2.3 Utility of Each Agent in Changing Strategies

Total utility, total duration of a project, the number of dual interaction actions, time loss and deformity loss in each strategy for each agent and the sum for case study is summarized at Table 5.4. Not surprisingly, agents completed the whole process at the longest path by 650 rounds by adopting p-p strategy, while agents have done it at the shortest paths by 456 and 457 rounds by adopting p-c-o and g-g strategies. This difference will result in 0.212719, 0.00110, 0.00000 time loss for p-p, g-g and p-c-o strategies respectively, which is the reason of failure of p-p strategy. Apart from the best and worst cases, the duration of other strategies varies between 459 and 465 rounds, which will have just subtle impact on the net utility. In terms of dominating strategy p-g-s, total duration of the project is 461 rounds, which means 5 round x 0.001097 = 0.00548 total time loss, 5 comes from 461-456 rounds (duration of strategy – optimum duration). This near optimum duration have impact on the achievement of p-g-s strategy.

In terms of utility of agents regardless of time and deformity loss, which will indeed impact on deformity loss, p-g-g and p-g-o strategies shows the minimum difference between objective and utility of an individual agent. The percentages of deformity of agents in these strategies are: 0.13%, 7.24% and 0.00% for Agent 1, 2 and 3 respectively (totally 7.39%). This deformity could directly bend the results of the study as the average of the total deformity is distributed to each agent according to their utility, which is 0.024597 for these strategies. It is obvious that the deformity of agents in p-p strategy is 0% of all, because in this strategy agents execute activities if only that activity is at the list of its objective (Table 5.3). In the context of deformity, agents get the maximum deformity loss when they are playing with p-d and g-z strategies by 29.85% and 23.36% respectively. In each case there is only agent 2 who cannot reach its objective. This make some sense for p-d because in p-d strategy agents start executing some actions, whenever one of them finishes, it gets the highest possible action, regardless of its stakeholders, resulting in failure of p-d strategy. However in such huge deformity loss of g-z strategy is most probably about the structure of the case. It can be said that, when agents look their risks, there are still some good options for agent 2, which is the greediest agent with nearly 0.527 objectives being more than twofold of other agents. In p-g-z case, we can say that agent 2 becomes far away from its objective just bit by bit, by even not realizing this issue.

In the case of winner strategy for whole project, which is p-g-s, deformities are 0.41%, 7.29% and 0.00% for Ag1, Ag2 and Ag3 correspondingly (totally 7.7%). It leads to 0.02565 deformity loss in total. By knowing that, however, one may ask that "Why p-g-g or p-g-o is not the dominant strategy instead of p-g-s if they are done better in terms of deformity?" the answer is clearly the impact of time loss, with p-g-s strategy, agents completed all tasks in 461 rounds while with other two strategy they do in 463. In other words the loss of 2 rounds is higher than 0.31% (7.7-7.39=0.31) deformity due to the distance between utility and objective.

The dominating strategies for different time intervals can also be seen at Table 5.5. As it can be seen p-c-o strategy starts with the highest point and it continues that till 11th round. After that time, p-p strategy rules the game for 301 rounds. It addresses that, if the disaster coordination center looks for short to medium term benefit, this strategy can also be adopted.

Table 5.4 Net utility of all strategies

Type of strategy	**Agents**	**Utility**	**Total duration (round)**	**Dual interaction**	**Time loss**	**Deformity loss**	**Net utility**
Greedy (g-g)	Soc. Ag	0,2683	457	9	0,00031	0,01785	0,2501
	Eco. Ag	0,4259			0,00049	0,02834	0,3971
	Env. Ag	0,2680			0,00031	0,01784	0,2499
	Total	**0,9623**			0,00110	0,06403	**0,8972**
Greedy objective (g-o)	Soc. Ag	0,2677	465	4	0,00275	0,01786	0,2471
	Eco. Ag	0,4257			0,00437	0,02840	0,3930
	Env. Ag	0,2682			0,00275	0,01789	0,2475
	Total	**0,9617**			0,00987	0,06416	**0,8877**
Greedy Zeuthen based (g-z)	Soc. Ag	0,2755	459	3	0,00095	0,02237	0,2522
	Eco. Ag	0,4040			0,00139	0,03281	0,3698
	Env. Ag	0,2794			0,00096	0,02269	0,2558
	Total	**0,9591**			0,00329	0,07787	**0,8779**
Greedy social welfare (g-s)	Soc. Ag	0,2681	459	5	0,00092	0,01782	0,2494
	Eco. Ag	0,4260			0,00146	0,02831	0,3962
	Env. Ag	0,2684			0,00092	0,01784	0,2496
	Total	**0,9626**			0,00329	0,06398	**0,8954**
Passive (p-p)	Soc. Ag	0,2441	650	0	0,05194	0,00000	0,1922
	Eco. Ag	0,5272			0,11216	0,00000	0,4151
	Env. Ag	0,2285			0,04862	0,00000	0,1799
	Total	**1,0000**			0,21272	0,00000	**0,7872**
Passive direct (p-d)	Soc. Ag	0,2655	460	0	0,00122	0,02758	0,2368
	Eco. Ag	0,3699			0,00169	0,03841	0,3297
	Env. Ag	0,3225			0,00148	0,03350	0,2876
	Total	**0,9580**			0,00439	0,09948	**0,8542**

Table 5.4 Net utility of all strategies (cont'd)

Passive greedy (p-g-g)	Soc. Ag	0,2438	463	6	0,00190	0,00609	0,2358
	Eco. Ag	0,4890			0,00381	0,01222	0,4730
	Env. Ag	0,2517			0,00196	0,00629	0,2435
	Total	**0,9846**			0,00768	0,02460	**0,9524**
Passive greedy objective (p-g-o)	Soc. Ag	0,2438	463	6	0,00190	0,00609	0,2358
	Eco. Ag	0,4890			0,00381	0,01222	0,4730
	Env. Ag	0,2517			0,00196	0,00629	0,2435
	Total	**0,9846**			0,00768	0,02460	**0,9524**
Passive greedy Zeuthen (p-g-z)	Soc. Ag	0,2411	460	3	0,00107	0,00696	0,2331
	Eco. Ag	0,4887			0,00217	0,01412	0,4724
	Env. Ag	0,2559			0,00113	0,00739	0,2473
	Total	**0,9857**			0,00438	0,02848	**0,9529**
Passive greedy social w. (p-g-s)	Soc. Ag	0,2431	461	4	0,00135	0,00633	0,2354
	Eco. Ag	0,4888			0,00272	0,01273	0,4733
	Env. Ag	0,2527			0,00141	0,00658	0,2447
	Total	**0,9847**			0,00548	0,02565	**0,9536**
Coward (p-c)	Soc. Ag	0,2654	461	0	0,00148	0,01264	0,2513
	Eco. Ag	0,4534			0,00254	0,02158	0,4293
	Env. Ag	0,2616			0,00146	0,01245	0,2477
	Total	**0,9805**			0,00548	0,04667	**0,9284**
Coward objective (p-c-o)	Soc. Ag	0,2570	456	0	0,00000	0,01079	0,2462
	Eco. Ag	0,4623			0,00000	0,01941	0,4429
	Env. Ag	0,2579			0,00000	0,01082	0,2471
	Total	**0,9773**			0,00000	0,04103	**0,9362**
Coward Zeuthen based (p-c-z)	Soc. Ag	0,2674	460	0	0,00119	0,01345	0,2527
	Eco. Ag	0,4493			0,00201	0,02260	0,4247
	Env. Ag	0,2625			0,00117	0,01320	0,2481
	Total	**0,9793**			0,00438	0,04925	**0,9256**

Then for just 21 rounds p-g-g and p-g-o strategies are seen at the top, however then p-p strategy gets the ball again for 160 rounds. By the round of 494, p-g-s strategy emerges at the top until the end of the process. This is because in p-p strategy, it was regardless of time until the round of 456, after that the net utility of strategies lasting longer start decreasing.

Table 5.5 Dominating strategy in different durations

Round	**Dominant strategy**	**Term**
1-11	p-c-o	Very short term
12-312	p-p	Very short to medium
313-333	p-g-g and p-g-o	Medium
334-493	p-p	Medium to long
494-650	p-g-s	Whole project

The number of dual interaction at Table 5.4 indicates the number of actions that was interrupted and taken by one of the other two agents, which has already been started by another agent. After this interruption, %5 of the total utility of an action is given as an interruption penalty. So agent, wishing to interrupt an action checks whether it is worthwhile to take that action or check for the new one. As it can be seen, in 5 of the 13 strategies, there was no any dual interaction upon any of the actions. In 2 of them there is no any negotiation as well (p-p, p-d). However, in 3 of them which are p-c, p-c-o and p-c-z agents are coward to be interrupted, so they negotiate beforehand. If they see that the action they want can be interrupted, then they do not choose that action. Total net utilities of agents with different strategies can be seen at Figure 5.2.

The utilities of each agent and total by considering time and deformity loss in dominating strategy can be seen at Figure 5.3. As it can be seen, agent 1 and agent 3 play with some similarity while agent 2 plays in its own way. The reason is the differences in objectives for each agent.

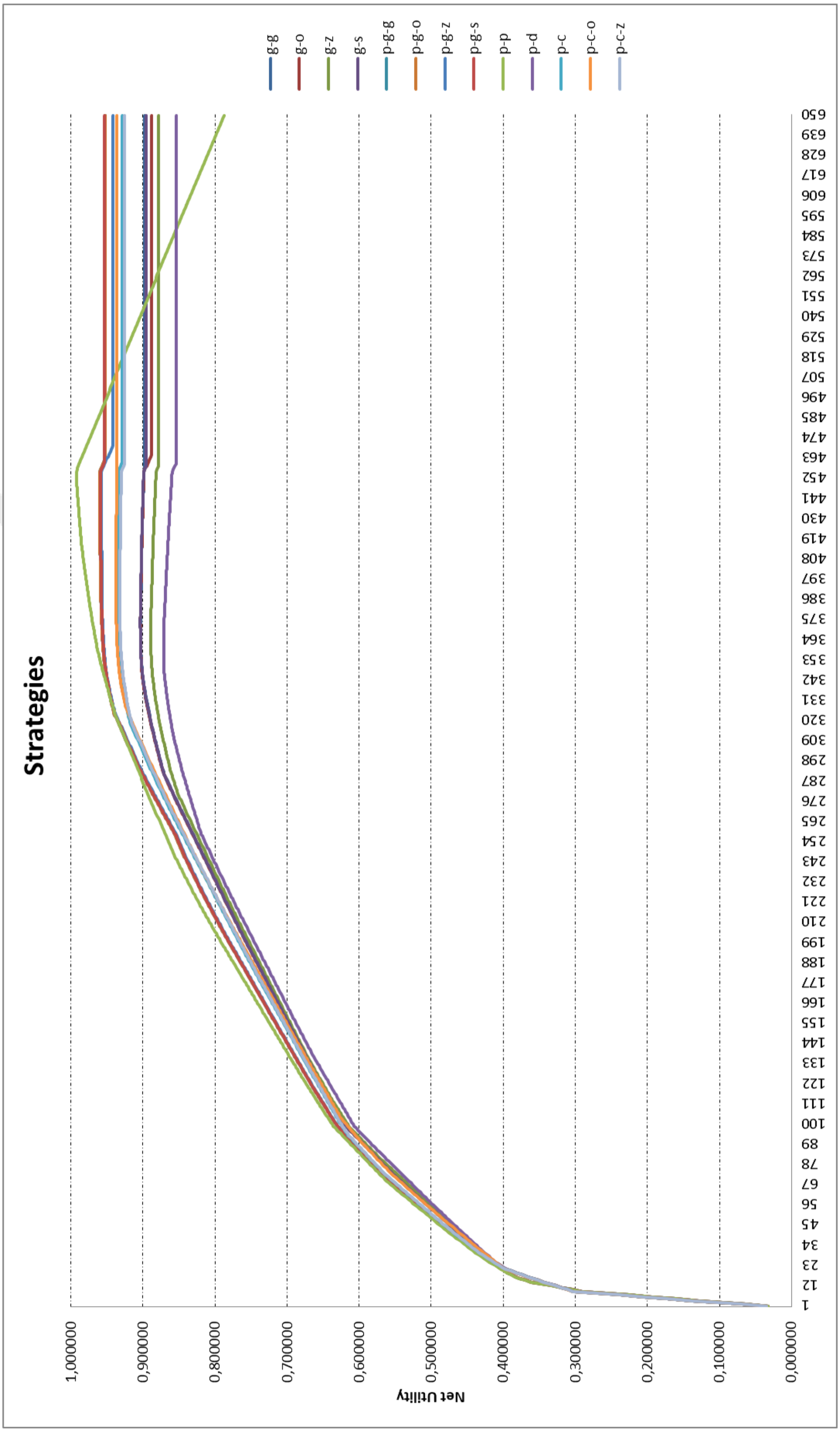

Figure 5.1 Strategies in changing duration

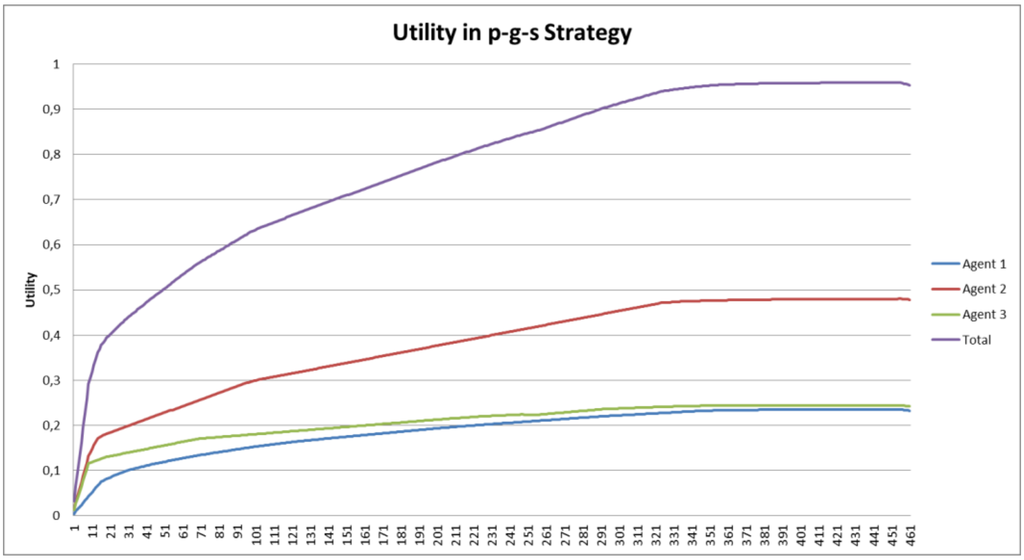

Figure 5.2 Utility of agents in dominating strategy (p-g-s)

At Figure 5.4, the objectives and utilities of each agent over time can be seen. Agent 1 and 2 cannot achieve their objectives, which was the reason of deformity loss, while agent 3 exceeds.

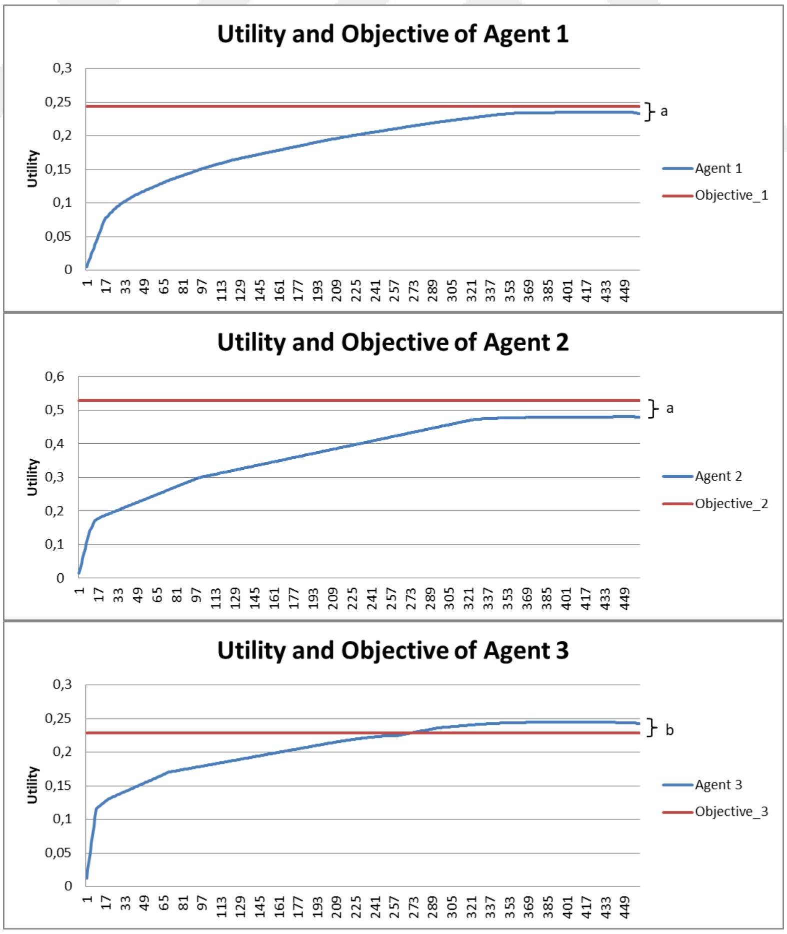

Figure 5.3 Objectives and utilities of each agent

At the figure, 'a' indicates the deformity amount and 'b' addresses the surplus amount. It could have been better for agent 3 to let others to do at the last parts of the game, it might be better for itself too, however, waiting for them at that time could result in time loss, which will probably not compensate the loss amount. The "course of action plan" in p-g-s strategy can be seen at Table 5.6.

As a result, from the light of action plan of dominating strategy, it can be said that Increasing legal conditions about flood, increasing the maintenance of storm water drainage capacity and afforestation actions are urgently needed to be hold. Then increasing the maintenance of transportation network and flood control mechanisms, planting the arid land and recruiting personal for emergency response team activities should be hold. Then it goes as similar to this process. At last, improving flood resistances in commercial and residential building, increasing the capacity of drainage systems for agricultural areas and, improvement of natural gas transmission and distribution capacity were determined as the last actions to hold. When we look at the actions needed to be done first, we see that most of them are the actions in land use, urban infrastructure and institutional capacity parameters respectively.

It is recommended for disaster coordination center to adopt actions with their sequence of dominating strategy so as to decrease flood risk in the district. Sensitivity analysis was carried out in order to grasp the impact of intervention penalty on the dominating strategy and net utility, which can be seen at Figure 5.5. As it can be seen when the penalty reaches 0.4, net utility sees its worst point, this is because any of the agents do not want to interfere any action by considering high penalty rate. Maximum utility is observed when there is no penalty. At figure 5.6, the impact of intervention penalty on duration of the project and the number of intervention of the dominating strategy can be seen. It is noteworthy that, when penalty is %5 there is a 4 interruption while penalty increases to %6, so do increase in the number of interruptions to 5. In normal case is does not make any sense, because increase in penalty will lead agents not to interrupt, however because of the complexity of the action gathering, somehow, there are 5 interruption observed.

It can also be said that the performance of coward objective strategy is remarkable, as without any dual interaction, it reaches nearly 0.936 net utility. It means that in some cases, p-c-o strategy can be a strongly dominating strategy.

Table 5.6. Actions in passive greedy social welfare strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B22	16	B3	9	B15	9
B56	9	B5	5	B17	10
B2	5	B34	5	B43	50
B13	10	B4	80	B20	4
B19	4	B39	225	B38	125
B37	16	B47	10	B54	10
B27	10	B31	16	B49	18
B53	1	B1	2	B16	1
B29	30	B35	29	B12	10
B50	20	B25	79	B32	10
B52	9			B21	10
B46	10			B45	35
B57	60			B41	3
B24	20			B48	14
B42	60			B36	18
B33	15			B51	18
B41	47			B18	6
B6	15			B35	1
B58	5			B44	5
B59	8			B23	10
B28	7			B28	3
B7	40			B25	11
B40	10			B26	80
B8	10				
B30	10				
Total round:	447		460		**461**

It should also be mentioned that surprisingly all of the p-g strategies were observed at the top of the processes. One may ask why net utility in strategies starting greedy approach (g-g, g-o, g-z, g-s) are so far away from the heading strategies. There is no any one reason for it, however, if unit utilities of actions in the path of one of the agents are so less than that of this case then all passive starting algorithms could fail. Then there will be a game of these 4 passive strategies, coward strategies and passive direct strategy, which will change the whole process of the project.

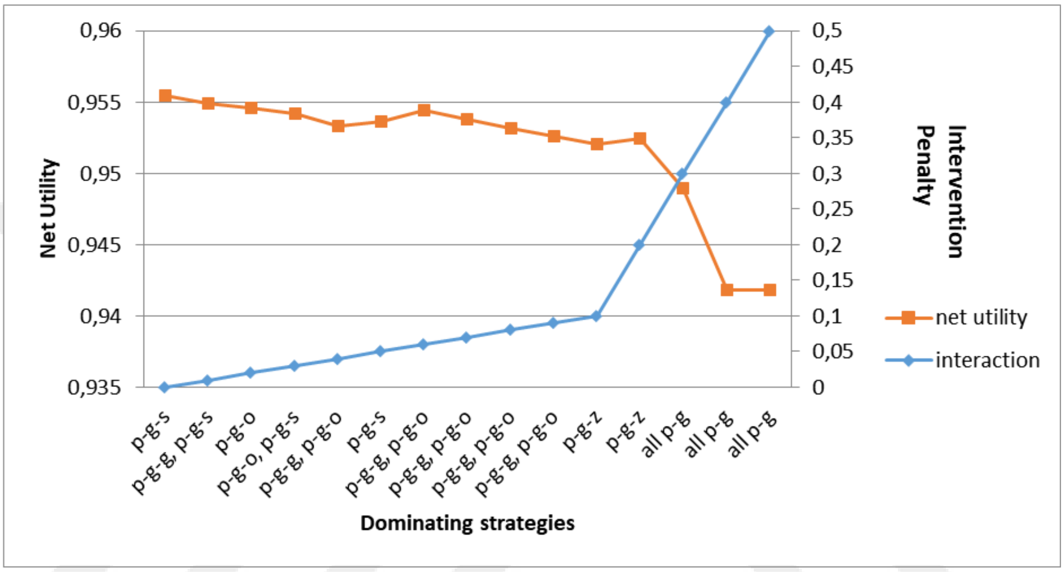

Figure 5.4 Effect of changing intervention penalty on net utility and dominating strategy

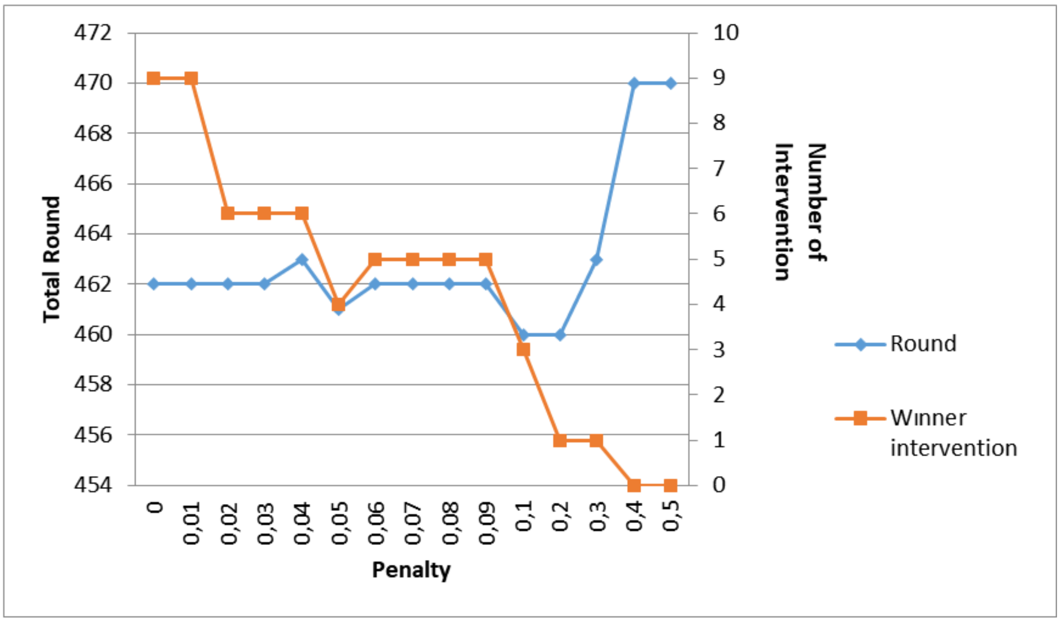

Figure 5.5 Effect of changing intervention penalty on total round and number of intervention

CHAPTER 6

RESULTS AND DISCUSSION

In this chapter findings of AHP and MAS processes will be discussed on the basis of previous research. First, AHP workshop results will be discussed in terms of impact level of flood risk factors and then MAS process will be criticized in terms of 13 strategies with interaction of 3 agents namely social-based, economic-based and environmental-based.

6.1 Effect of Controllable Flood Risk Factors Having Impact on Built Environment

The results of AHP workshop show that urban infrastructure and land use factors have the highest impact on flood loss level. Land use and urban infrastructure were seen at [182] as elements at risk for the case of future floods which is expected to increase due to climate change. As the inconsistency of the main factor cluster is 0.021, judgements are acceptable. However, there is no any correlation observed between frequency analysis and relative weights of each main factor.

6.1.1 Effects of Institutional Capacity Factors

"Institutional capacity" main factors were concluded as the third most important main factor by 16.1%. The capacity of institutions and the interaction of them is seen at [183] as one of the major reasons of flooding. In this cluster, the correlation was observed as nearly 0.62 between frequence analysis and the weights of factors which is noteworthy. The results show that not surprisingly "flood control mechanisms" and "flood response plan" sub factors are the most important factors. Different flood control measure options were studied at [79] and it was addressed that, flood control mechanisms are not only about the strength of these measures, but they have also some social and environmental benefits. This could give some insights into the reason of high relative weight of this factor in its cluster. In terms of flood response plan, it is obvious that most of the institutions working on flood disaster coordination are working on the development of flood response plan with their personnels, vehichles and accessibilities to all services or sufferers. It is also not surprising that this sub factor was appeal to most of the experts. For instance, vehicles and equipments as flood response measures were seen at [131] as important resources for threatening flood emergencies. In reverse, “capacity of meteorological observation station” is seen as the least important factor by experts, this is because the impact of this sub factor is not about flooding itself, it is actually about the quantity of rain and its warning time.

6.1.2 Effects of Urban Infrastructure Factors

“Urban infrastructure capacity” main factor is concluded as the most important factor, due to the impact of “water supply and sanitation infrastructure capacity” and “transportation network capacity” which reach 53% and 25.8% respectively in their inner cluster. There was no any observed big impact of telecommunication, electrity or natural gas systems capacity over flood risk apart from that they are one of the elements at risk. Correlation coefficient in this cluster was observed as 0.86 between frequency analysis and the weights of criteria, which is also a remarking point. It was addressed at [184] that urban drainage capacity and the failure of it is one of the main causes of flooding after heavy rainfalls. It was emphisiced at [132] that the reason of the frequency in flash flooding is ageing infrastructure, as urbanization generates higher and higher runoff volumes. In most of the studies drainage capacity is seen as the main causes of urban flooding, which makes it reasonable for this factor to be at the head of its cluster. Besides, vulnerability of flood prevention activities is mainly based on transportation, communication and medical treatment. Clear and convenient roads with acceptable traffic have direct link to the prevention of flood [136].

6.1.3 Effects of Land Use Factors

Because of the impact of factors namely “special public use building rate”, “residential building rate”, “public infrastructure rate” and “historical and archeological sites” by relative weights of 22.4, 20.2, 20.1, 12.3%; land use cluster were concluded as the second most impactful factor having impact on flood loss level. There were no correlation observed between frequency analysis and the weights of each factor. Even though “special public use building rate” have the highest weight of all, it has just been mentioned in the frequency analysis at 7 times, which indicates that there is a literature gap in this issue. Besides, special public buildings such as hospitals, health facilities, command centers are some of the strategic elements in case of crisis [135]. It is also crucial that “historical buildings and archeological sites” were not observed in the literature in the context of their susceptibility to flooding. As river environments are described in the context of their heritage values [128], such places with spiritual values should be emphasized so as to decrease their vulnerability to flooding. Finding also corresponds to “agricultural usage rate” having the least impact of flood loss level in “land use” cluster. However, agricultural usage was observed in the literature with a variety of studies. It might be concluded that practically agricultural usage rate in terms of flood loss level is not as important as it is focused on the literature.

6.1.4 Effects of Superstructure Capacity Factors

Superstructure capacity factor was found to be contributing flood loss level more than “demographic and social”, and “ecological” factors in goal cluster by 11.2%. However, when the correlation is concerned, surprisingly subtle negative correlation is observed between the results of frequency analysis and the weights of the factors in this cluster. The finding also indicates that “existance of basement housing” factor holds largest weight among the “superstructure capacity” cluster, however there were just a few studies observed tackling this issue. Basement flooding exposes residents to health risk and decrease in the value of their property, besides, social economic and environmental aspects of it is not ignorable. Therefore it makes sense due to the highest weight of this criterion in its class. The second most impactful factor in the cluster is “durability of building” by 14%. It ıncludes damage to sturucture and property, content and outside property as well as clean up cost for building. These costs were used at [125] to achieve mathematical model for urban damage. It can also be said that “floor area coefficient” and “rate of building without permission from municipality” factors were mentioned in studied papers just by 1 and 3 respectively. As they reach the weights of 12.9 and 10.1% respectively, which is not as less as it is supposed, there is a need to focus more on these issues. There are some differences observed between the focus of institutions and academics over flood disaster management. A surprising point in the cluster is that “rate of building with insurance” gets the least weight among all, however, it was mentioned at most in studied papers by 13, which indicates the same difference between institutions as mentioned previously.

6.1.5 Effects of Demographic and Social Factors

Demographic and social cluster was found as the second least important factors of all just above the ecologic cluster. In this cluster, there is no any significant correlation observed in terms of frequency analysis and weights of actions. Even though "population density" factor were mentioned mostly in the cluster by 19 times for studied papers, it is found to be the second least important factor just above the "income level" in terms of its weight. "Awareness" is found to be the most important factor by 34.2% followed by "level of education" by 25.5%. As fatality rate have direct link to behavior of people for changing situation in case of flooding, awareness of public becomes more crucial. It was addressed at [4] that awareness, education and warning appear to be the key factors decresing flood mortality rates. It was addressed at [185] that the difference in knowledge between experts and public over risk of flood affects efficiency of the warning process, especially for flash flood in which it last for nearly six hours after a heavy rainfall event observed. The high score of awareness is acceptable; however, it is hard to understand the reason of the fewer tendencies of experts over "income level", as the level of income have direct link to the vulnerability of people [2].

6.1.6 Effects of Ecologic Factors

Ecologic cluster were found the least important cluster according to experts joined the AHP workshop, by 4.8%. "Water pollution risk" and "soil pollution and erosion risk" were found the most important factors by 39.8 and 31.5% respectively, while that of "fauna associated risk" is found to be the least important factor by 10.5%. The correlation coefficient is found to be 0.63 between frequency analysis and the weights of the factors in the cluster. "Fauna associated risk" was mentioned just 1 time in the studied papers, which addresses the necessity of the study over this issue. In the context of pollution, it is one of the major indicators of flood vulnerability in environmental terms, as it may cause water diseases [2]. Pollution load of flood water at [118] were also seen as one of the flood characteristics factor in household vulnerability function.

6.2 Effects of Flood Mitigation Measures in Changing Strategies

In this study, 59 flood mitigation measures were determined having impact on flood loss level. These measures were allocated to social, economic and environmental agents by focusing on 13 strategies in the context of MAS. As a result, one of the strategies was choosen as it gives maximum utility, which is “passive greedy social welfare” strategy. The result of MAS gives a sequence of measures to work on in timely manner for institutions working on disaster risk reduction. The sequence of measures shows that assigning the measures to social, economic and environmental agents could affect decision making processes positively by focusing on three dimension of sustainability meantime. The interaction of agents in the context of different strategies directly affects the sequence of measures. In some of the strategies, one of the agents can hold an action that has already been started by another agent, if they still want to hold that activity by undertaking intervention penalty. It was observed that, total utility in g-g, g-o, g-z and g-s are higher than p-p and p-d strategy. It means that by having dual interaction on mitigation actions, there are higher utilities observed. However, it is also crucial that agents in coward strategy (p-c) reach higher utility than g-g, g-o, g-z and g-s strategy.

This result invalidate one of the hypothesis of this study as coward strategy gives more utility than greedy strategies, without considering passively starting ones. When we look at the coward strategy with objective based or zeuthen based, the utility increases more. However, when we look at the passively starting strategies, we found that p-g-s strategy shows the highest utility in overall. In such strategies, agents starts as if they are passively acting but when one of the agents does not find any other action to do, agents become greedy. Even though such passively starting strategies give higher results, it is because of the characteristics of the case study used in this research. Because if in another case one of the agents has dominating actions in its objective, but others have actions with much less unit utility, it is inevitable for such strategies to fail. For such occasions, one of the coward strategies will most probably be a dominating strategy. In the following part, so as to compare different strategies, dominating strategy (p-g-s) and coward objective strategy (p-c-o) will be discussed

6.2.1 Social Effects

In passively starting strategies, social outlook on flood disaster mitigation starts from the action named B22 stands for “increase the legal conditions and regulations” which was addressed at [186] as one of the most cost-effective flood risk management measures. In direct, greedy or coward strategies, however, B5 action which stands for “maintenance of transportation network” was seen at the first desire of social agent, as this action have higher utility for social agent. By focusing on dominating strategy B22 action was fallowed by flood mitigation measures named B56, B2, B13, B19 and B37 which are: “recruit personel for emergency services and for community volunteer groups”, “maintenance of water supply facilities”, “build flood control mechanism in coastal sides”, “train public in flood disaster and increase the awareness of them” and “develop flood response plan and increase the capacity of emergency response team and vehicles” respectively. These actions are the same for all passively starting strategies actually. The results indicate a meaningful outcome as these 6 actions were suggested by other authors to mitigate flood risks. In comparison, in p-c-o strategy social agent hold B5, B22, B13, B19, B37 and B27 actions respectively. The only differences of this strategy from p-g-s are B5 and B27, which are “maintenance of transportation network” and “improve early warning systems” actions. As action B5 has higher utility than B22, if very urgent mitigation measure should be done, then p-c-o strategy will be a ruling strategy (see Table 5.5).

In the case of B56 it was addressed at [7] that availability of staff is one of the reasons of not adopting even the best programs developed. In the case of B2, water supply infrastructure is one of the most critical infrastructures as it carries freash water, the vulnerability of such infrastructures should be decreased, because othervise such disastrous events could cause the ripple effect [7]. In the case of B13, adopting flood resilient construction and their maintenance practices were seen at [144] as one of the physical protection measures for coastal flooding.

As last measures, B30 and B8 was decided by social agent to hold at the end of the course of action which are; “increase the capacity of drainage and create system for optimum soil water level (irrigation) in agricultural areas” and “improvement of natural gas transmission and distribution systems” respectively. The reason for B30 to be at the end of the process is that, in the case area, there are just a few areas for agricultural use.

6.2.2 Economic Effects

In all strategies, economic agent chooses B3 action to mitigate flood risk in mostly economic term, which is “maintenance of storm water drainage facilities”. It makes sense because inefficiency or not adequate maintenance of drainage facilities is seen as one of the major factors aggravating hazardousness of flood [79], [102], [131]. For the next measures; B5, B34, B4, B39 and B47 were choosen by economic agent in p-g-s strategy as firstly focus areas which are “maintenance of transportation network”, “increase the maintenance of levees, dykes, embankments and other flood control mechanisms”, “increase the capacity of storm water drainage facilities”, “put an area in urban regeneration site”, and “change the building code in terms of structural material” respectively. In that of p-c-o strategy sequence of measures are B34, B56, B4, B39 and B48. The differences are B56 and B48 in coward strategy which stand for “recruit personel for emergency services and for community volunteer groups” and “promote people to change building material or to build flood walls so as to increase durability of buildings to flood” respectively. It is noteworthy that action B56 is seen as the duty of social agent in p-g-s strategy while that of economic agent in p-c-o strategy. To choose the most adequate strategy, it is also necessary to see the urgency of flood mitigation (see Table 5.5)

In terms of transportation networks, action B5, it is clear that vulnerability of an area is largely depends on the transportation network [136]. Even though only traffic interruption costs due to flooding is concerned, it reaches %4 of all losses in the case study at [125]. In terms of B34, it can be said that in order to decrease the risk of flood especially in flood plains, one of the main measures are constructing levees, dykes, embankments and so on. Such man-made flood control structures as embankments affects flood characteristics directly [125]. Such mechanisms have direct impact on economic loss as they could decrease the depth of flood especially in flood plains. The necessity of B4 is similar to B2 as inner indicates the capacity latter addresses the maintenance of water drainage facilities. As maintenance requires less time, cost and effort it lasts for 5 round where that of capacity 80. In terms of B47, as indicated at [118] especially for buildings in flood plain, building codes should cover water proofing and which does not cover in the case study area.

For the ending rounds, actions named B25 and B35 were observed as desires of economic agent which are improve flood resistance in residential buildings and increase the capacity of meteorological observation stations. This is not because of the low impact of these measures, but because of the difficulty of the practices of them. These two measures were first started by environmental agent but then taken by economic agent so as to increase social welfare. The corresponding rounds of them are 90 and 30 respectively.

6.2.3 Environmental Effects

In all strategies, environmental agent chooses B15 action to mitigate flood risk in mostly environmental term, which is “afforestation”. It is not actually a flood mitigation option in the absence of human activity; however, because of such human interactions nature of the habitat is changing, as a result, afforestation becomes an action to take to mitigate flood risks [118]. This measure is followed by B17, B43, B20, B38 and B54 in p-g-s strategy which are “vegetate soil without any vegetation”, “increase the number of parks and open spaces”, “control industrial and other buildings emitting chemical or hazardous waste if there is a possibility to touch to flood water”, “dredge, widen or remediate streams and channels” and “create a team to care flora in case of flooding, preserve biodiversity” respectively. In that of p-c-o strategy, measures were sequenced as B15, B17, B2, B43, B50 and B20. Even though first three measures are the same in both strategies, B2 and B50 measures were at the duty of environmental agent in p-c-o strategy while not in that of p-g-s, which are “maintenance of water supply facilities” and “change building code in terms of basement” respectively. These 2 actions are the dusty of social agent in p-g-s strategy, which indicates more meaningful match-up.

In terms of B17, as destruction of vegetation for the purpose of urbanization there are just subtle areas remaining natural, there is a need of vegetating such topography in order for flood water to infiltrate [123]. In terms of B43, which indicates the importance of parks and open spaces, increasing the number of parks or greened spaces could impact on the reduction of surface runoff [102]. As such places can be used for multi purposes for instance recreational activities or tourist attractions; their impact on the wellbeing of a community is inevitable [102]. The importance of B20 to decrease loss level of flood, which is related to pollution due to the impact of industrial buildings, is indubious. Industries, as a source of pollution in case of flood vulnerability, is addressed at [2] to be the most important factor in the cluster of pollution, which is one of the environmental indicators. In terms of B38, stands for the imporevement of streams and channel by widening them, it is broadly adopted to increase the capacity of the river channel [118]. In terms of B54, creating team to care flora tand preserve biodiversity, it was choosen as a need at [145] in environmental dimension, below the layer of maintenance of biodiversity.

Just before the end of the process for environmental agent, B25 and B26 measures were observed as the last duty of the agent, which are “improve flood resistance in residential buildings” and “improve flood resistance in commercial buildings” respectively. Even though B25 was hold by environmental agent first, so as not to loss time for the most important measure for that time, it was taken by economic agent as economic agent has more capability over this issue. Though it would be better for economic agent to hold B26, it will inevitably decrease the utility of the whole system as a result of time loss for other agents.

As a conclusion of the proposed model, it can be said that these processes are similar to real-life examples of flood mitigation plan of disaster coordination centers as sometimes one of the actors start to hold some actions, and then others continue for the sake of social welfare. Social, economic and environmental conditions of actions, current conditions of the actions and suitability of actions’ queries in the model make the model more real-life process too. Moreover, penalties because of time loss, deformity loss and dual interventions make the model indicate more realistic solutions. At the end, model gives us a dominating strategy for flood disaster mitigation action plan, so-called “course of action plan” which shows the maximum utility However, the best strategy for medium or short term can differ from that of long term, which indicates that for some specific resource of fund, we might cut the project and select the best plan for that case.

As p-g-s strategy is concluded as a dominating strategy, it is suggested that for other cases the best strategy can change. To consider social welfare, the district can become more flood resilient community. It has been concluded that maintenance of storm water drainage facilities, afforestation, improvement of legal conditions of flood and maintenance of transportation network capacity actions are the most crucial ones for selected case. It has been shown that for some actions in specific conditions dual intervention of actions may result in more sustainable solutions.

A model was presented in this study to distribute flood mitigation measures. However, in the case study only one district was studied. The model can be extended with more cases to a province and more a national level. A simulation can be developed to suit national level by running the proposed model for each district. Then the budget of disaster coordination measures can be distributed with better allocation for various districts.

For further studies, determination of predecessors of each action with resource leveling could present more project-based solution by giving map of each action similar to those used at most of the construction projects. Furthermore, this study can be seen as a baseline of the project of flood disaster management. Actual duration, cost and effort can be implemented for future works, then dynamic continuous solution can be achieved. As risk reduction, response and reconstruction phases require cooperation between institutions holding these activities, the model can be integrated with flood response and reconstruction phases.

Moreover, as some measures may increase the retention of the nature, those having negative impact on it can be determined and limited, by giving “retention of nature penalty.” By doing all, main aim of this study can be achieved, which is to find sustainable solution for flood disaster management, in the context of project management.

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APPENDIX-A

WORKSHOP- DETERMINATION OF THE FACTORS AFFECTING BUILT ENVIRONMENT IN ORDER TO DEVELOP MULTI AGENT INTEGRATED RISK MANAGEMENT PLATFORM FOR FLOOD DISASTER MANAGEMENT

In Yildiz Technical University, Department of Civil Engineering, Construction Management Division, thesis topic “Development of an Integrated Multi-agent Risk Management Platform for Flood Disaster Management”, it is aimed to determine risks of flood disaster so as to allocate tasks to responsible institutions by looking at various perspective and using multi-dimensional factors affecting flooding.

In this context, as a result of literature review, 6 main and 35 sub factors determined having impact on built environment (Figure A.1, Table A.1-8).

Subsequently proposed model and risk allocation platform requires the determination of the loss level of flood factors. This survey study was formed so as to determine priorities amongst flood factors.

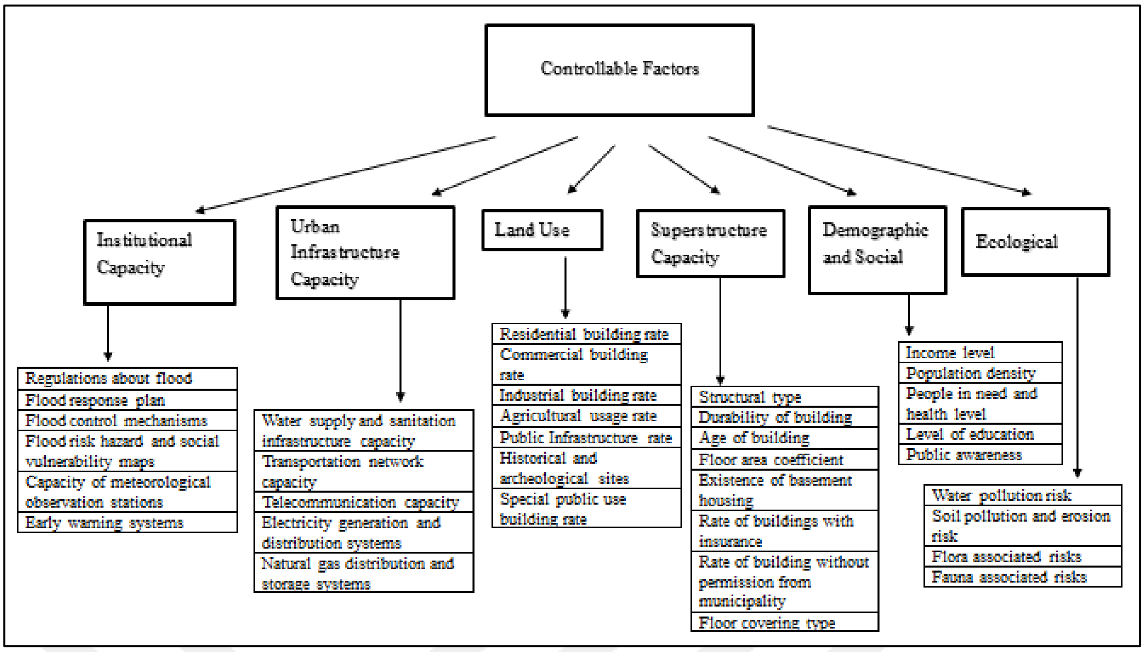

Figure A.1 Controllable flood factors affecting built environment

Table A.1 Controllable flood factors affecting built environment and their meanings

I	Institutional capacity	It includes such parameters as regulations, flood response plan, early warning systems and so on. They are mostly related with the capacity of any institutions that are responsible to flood events.
U	Urban infrastructure capacity	It includes such parameters as water supply and sanitation capacity, transportation network capacity, telecommunication capacity, electricity generation and distribution system capacity, natural gas distribution system capacity.
L	Land use	It includes such parameters as residential building rate, commercial building rate, industrial building rate, agricultural usage rate, historical and archeological site rate and special public use building rates. For these parameters increase in them could result in imperviousness as well as economic vulnerability.
S	Superstructure capacity	It includes such parameters as structural type, durability, age of building, floor area coefficient, existence of basement, rate of buildings with insurance, rate of building without permission from municipality and floor covering
D	Demographic and social	It includes such parameters as income level, population density, disability and health condition, level of education and awareness of people.
E	Ecological	It includes such parameters as water pollution, soil pollution, flora and fauna associated risks.

Table A.2 Institutional capacity

I1	Regulations about flood	Regulations related to flooding, their sufficiency
I2	Flood response plan	All sort of preparedness including number of personnel and vehicles of head offices in terms of response plan
I3	Flood control mechanisms	Dams, levees or water retention systems' capacity
I4	Flood risk hazard and social vulnerability maps	All type of risk and vulnerability maps and their applicability
I5	Capacity of meteorological observation station	The capacity and sufficiency of meteorological observation stations
I6	Early warning systems	Early warning systems and their applicability

Table A.3 Urban Infrastructure

U1	Water supply and sanitation capacity	Storm water and waste water drainage, water sanitation system capacities
U2	Transportation network capacity	Metro, highways, secondary roads
U3	Telecommunication capacity	Telecommunication system capacities and their vulnerabilities
U4	Electricity generation and distribution systems	Electricity system capacities and their vulnerabilities
U5	Natural gas distribution and storage systems	Natural gas system capacities and their vulnerabilities

Table A.4 Land use

L1	Residential building rate	Residential building area to total area
L2	Commercial building rate	Commercial building area to total area
L3	Industrial building rate	Industrial building area to total area
L4	Agricultural usage rate	Agricultural area to total area
L5	Public infrastructure rate	Public infrastructure area to total area
L6	Historical and archeological site rate	Historical area to total area
L7	Special public use building rate	Special public use areas to total area

Table A.5 Superstructure capacity

S1	Structural type	Material used in carrier system such as concrete, steel, wooden
S2	Durability of building	Durability of building to flood touches
S3	Age of building	Age of building as it can change the durability
S4	Floor area coefficient	As floor area coefficient could change the volume of water touches to building
S5	Existence of basement housing	The basement condition
S6	Rate of buildings with insurance	As building with insurance could be less vulnerable in terms of post disaster
S7	Rate of building without permission from municipality	If there is a no permission of building it is hard to control the vulnerability of them
S8	Floor covering type	The covering material of building or any structures and they can change water insulation coefficient

Table A.6 Demographic and social

D1	Income level	Whether income is enough to cover for post disaster measures
D2	Population density	Vulnerability over population density
D3	People in need and health level	People with low health level are more vulnerable for before, during and post flood measures
D4	Level of education	Level of education could alter the action of people
D5	Public awareness	Awareness could alter the way people struggle with flood

Table A.7 Ecological

E1	Water pollution risk	From sewage systems or chemically dangerous places if water is polluted so do people and their properties as well as water resources
E2	Soil pollution and erosion risk	Soil pollution could create risk for cultivations
E3	Flora associated risks	It addresses any sort of natural vegetation
E4	Fauna associated risks	It addresses animals' vulnerability

1. INFORMATION OF PARTICIPANT

Name Surname	
Institution and Position	
Experience	
Works related to disaster management	

2. SURVEY

a. Main Factors

1) Controllable risk factors affecting flood loss level

Question: Which parameter is how much more important than other?

	I	U	L	S	D	E
I	1.0					
U	/ / /	1.0				
L	/ / /	/ / /	1.0			
S	/ / /	/ / /	/ / /	1.0		
D	/ / /	/ / /	/ / /	/ / /	1.0	
E	/ / /	/ / /	/ / /	/ / /	/ / /	1.0

I Institutional capacity
U Urban Infrastructure
L Land use
S Superstructure capacity
D Demographic and social
E Ecological

b. **Sub Factors**

1. Institutional Capacity

Question: Which parameter is how much more important than other?

	I1	I2	I3	I4	I5	I6
I1	1.0					
I2	/ / /	1.0				
I3	/ / /	/ / /	1.0			
I4	/ / /	/ / /	/ / /	1.0		
I5	/ / /	/ / /	/ / /	/ / /	1.0	
I6	/ / /	/ / /	/ / /	/ / /	/ / /	1.0

I1 Regulations
I2 Flood response plan
I3 Flood control mechanisms
I4 Flood risk hazard and social vulnerability maps
I5 Capacity of meteorological observation station
I6 Early warning systems

2. Urban Infrastructure

Question: Which parameter is how much more important than other?

	U1	U2	U3	U4	U5
U1	1.0				
U2	/ / /	1.0			
U3	/ / /	/ / /	1.0		
U4	/ / /	/ / /	/ / /	1.0	
U5	/ / /	/ / /	/ / /	/ / /	1.0

U1 Water supply and sanitation capacity
U2 Transportation network capacity
U3 Telecommunication capacity
U4 Power generating systems capacity
U5 Natural gas transmission and distribution system capacity

3. Land Use

Question: Which parameter is how much more important than other?

	L1	L2	L3	L4	L5	L6	L7
L1	1.0						
L2	/ / /	1.0					
L3	/ / /	/ / /	1.0				
L4	/ / /	/ / /	/ / /	1.0			
L5	/ / /	/ / /	/ / /	/ / /	1.0		
L6	/ / /	/ / /	/ / /	/ / /	/ / /	1.0	
L7	/ / /	/ / /	/ / /	/ / /	/ / /	/ / /	1.0

L1 Residential building rate
L2 Commercial building rate
L3 Industrial building rate
L4 Agricultural usage rate
L5 Public infrastructure rate
L6 Historical and archeological site rate
L7 Special public use areas rate

4. Superstructure Capacity

Question: Which parameter is how much more important than other?

	S1	S2	S3	S4	S5	S6	S7	S8
S1	1.0							
S2	/ / /	1.0						
S3	/ / /	/ / /	1.0					
S4	/ / /	/ / /	/ / /	1.0				
S5	/ / /	/ / /	/ / /	/ / /	1.0			
S6	/ / /	/ / /	/ / /	/ / /	/ / /	1.0		
S7	/ / /	/ / /	/ / /	/ / /	/ / /	/ / /	1.0	
S8	/ / /	/ / /	/ / /	/ / /	/ / /	/ / /	/ / /	1.0

S1 Structural type (Steel, concrete, wooden)
S2 Durability of building
S3 Age of building
S4 Floor area coefficient
S5 Existence of basement housing
S6 Rate of buildings with insurance
S7 Rate of building without permission from municipality
S8 Floor covering type

5. Demographic and Social

Question: Which parameter is how much more important than other?

	D1	D2	D3	D4	D5
D1	1.0				
D2	/ / /	1.0			
D3	/ / /	/ / /	1.0		
D4	/ / /	/ / /	/ / /	1.0	
D5	/ / /	/ / /	/ / /	/ / /	1.0

D1 Average Income level
D2 Population density
D3 Disability rate and health level
D4 Level of education
D5 Awareness

6. Ecological

Question: Which parameter is how much more important than other?

	E1	E2	E3	E4
E1	1.0			
E2	/ / / / / / / / / / /	1.0		
E3	/ / / / / / / / / / /	/ / / / / / / / / / /	1.0	
E4	/ / / / / / / / / / /	/ / / / / / / / / / /	/ / / / / / / / / / /	1.0

E1 Water pollution risk
E2 Soil pollution and erosion risk
E3 Flora (vegetation) associated risk
E4 Fauna associated risk

For anybody joining the study, the information about them will not be shared in any case. Thanks in advance.

APPENDIX-B

RESULTS OF OTHER STRATEGIES

Apart from the ruling strategy, action and their rounds for 3 of the predetermined agents can be seen at Table B.1-12.

Table B.1 Actions in passive strategy

Social agent	**Round**	**Economic Agent**	**Round**	**Environmental Agent**	**Round**
B22	16	B3	9	B15	9
B56	9	B5	5	B17	10
B2	5	B34	5	B43	50
B13	10	B4	80	B20	4
B19	4	B39	225	B38	125
B37	16	B45	35	B54	10
B27	10	B33	15	B49	18
B53	1	B48	14	B16	1
B29	30	B47	10	B12	10
B50	20	B36	18	B32	10
B52	9	B31	16	B21	10
B46	10	B51	18		
B57	60	B1	2		
B24	20	B59	8		

Table B.1 (cont’d)

B42	60	B23	10		
B41	50	B25	90		
B6	15	B26	80		
B18	6	B30	10		
B35	30				
B44	5				
B58	5				
B28	10				
B7	40				
B40	10				
B8	10				
Total:	461		**650**		257

Table B.2 Actions in passive direct strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B2	5	B56	9	B4	80
B19	4	B13	10	B50	20
B37	16	B39	225	B20	4
B27	10	B33	15	B45	35
B53	1	B48	14	B38	125
B29	30	B47	10	B54	10
B43	50	B36	18	B49	18
B52	9	B31	16	B16	1
B46	10	B18	6	B12	10

Table B.2 (cont'd)

B57	60	B1	2	B32	10
B24	20	B6	15	B51	18
B42	60	B59	8	B44	5
B41	50	B28	10	B58	5
B35	30	B26	80	B23	10
B7	40			B25	90
B40	10				
B21	10				
B8	10				
B30	10				
Total round:	456		452		**460**

Table B.3 Actions in greedy greedy strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B2	5	B56	9	B4	4
B13	10	B4	76	B43	50
B19	4	B39	192	B53	1
B37	16	B48	14	B29	30
B27	10	B47	10	B20	4
B39	33	B36	18	B45	35
B50	20	B31	16	B38	125
B52	9	B35	26	B54	10
B46	10	B25	82	B49	18
B57	60			B16	1

Table B.3 (cont'd)

B24	20		B12	10
B42	60		B32	10
B33	15		B51	18
B41	50		B18	6
B6	13		B6	2
B58	3		B1	2
B59	8		B35	4
B28	9		B44	5
B7	39		B58	2
B40	10		B23	10
B26	31		B28	1
			B25	8
			B7	1
			B26	49
			B21	10
			B30	10
			B8	10
Total round:	456	**457**		455

Table B.4 Actions in greedy objective strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B2	5	B56	9	B4	4
B13	10	B4	76	B43	50
B19	4	B39	192	B53	1

Table B.4 (cont'd)

B37	16	B48	14	B29	30
B27	10	B47	10	B20	4
B39	33	B36	18	B45	35
B50	20	B31	16	B38	125
B52	9	B6	7	B54	10
B46	10	B59	8	B49	18
B57	60	B23	5	B16	1
B24	20	B25	90	B12	10
B42	60			B32	10
B33	15			B51	18
B41	50			B18	6
B1	2			B6	8
B35	30			B44	5
B40	10			B58	5
B26	80			B23	5
				B28	10
				B7	40
				B21	10
				B30	10
				B8	10
Total round:	**465**		459		444

Table B.5 Actions in greedy zeuthen-based strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B2	5	B56	9	B4	14
B19	4	B13	10	B43	50
B37	16	B4	66	B53	1
B27	10	B45	35	B29	30
B39	78	B39	147	B50	20
B52	9	B33	15	B20	4
B46	10	B48	14	B38	125
B57	60	B47	10	B54	10
B24	20	B31	16	B49	18
B42	60	B18	6	B16	1
B41	49	B1	2	B41	1
B6	15	B35	30	B12	10
B59	8	B26	80	B32	10
B28	10			B36	18
B7	40			B51	18
B40	10			B44	5
B21	10			B58	5
B8	10			B23	10
B30	10			B25	90
Total round:	455		454		**459**

Table B.6 Actions in greedy social welfare strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B2	5	B56	9	B4	4
B13	10	B4	76	B43	50
B19	4	B39	192	B53	1
B37	16	B48	14	B29	30
B27	10	B47	10	B20	4
B39	33	B36	18	B45	35
B50	20	B31	16	B38	125
B52	9	B35	26	B54	10
B46	10	B25	84	B49	18
B57	60			B16	1
B24	20			B12	10
B42	60			B32	10
B33	15			B51	18
B41	50			B18	6
B6	13			B6	2
B59	8			B1	2
B28	10			B35	4
B7	40			B44	5
B40	10			B58	5
B21	10			B23	10
B8	10			B25	6
B30	10			B26	80
Total round:	454		**459**		455

Table B.7 Actions in passive greedy greedy strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B22	16	B3	9	B15	9
B56	9	B5	5	B17	10
B2	5	B34	5	B43	50
B13	10	B4	80	B20	4
B19	4	B39	225	B38	125
B37	16	B47	10	B54	10
B27	10	B36	5	B49	18
B53	1	B31	16	B16	1
B29	30	B59	8	B12	10
B50	20	B23	10	B32	10
B52	9	B25	90	B21	10
B46	10			B45	23
B57	60			B41	27
B24	20			B48	14
B42	60			B36	13
B45	12			B51	18
B33	15			B35	1
B41	23			B44	5
B6	15			B58	5
B18	6			B28	10
B1	2			B7	9
B35	29			B26	41
B7	31			B30	10
B40	10			B8	10
B26	39				
Total round:	462		**463**		443

Table B.8 Actions in passive greedy objective strategy

Social agent	Round	Economic agent	Round	Environmental agent	Round
B22	16	B3	9	B15	9
B56	9	B5	5	B17	10
B2	5	B34	5	B43	50
B13	10	B4	80	B20	4
B19	4	B39	225	B38	125
B37	16	B47	10	B54	10
B27	10	B36	5	B49	18
B53	1	B31	16	B16	1
B29	30	B59	8	B12	10
B50	20	B23	10	B32	10
B52	9	B25	90	B21	10
B46	10			B45	23
B57	60			B41	27
B24	20			B48	14
B42	60			B36	13
B45	12			B51	18
B33	15			B35	1
B41	23			B44	5
B6	15			B58	5
B18	6			B28	10
B1	2			B7	9
B35	29			B26	41
B7	31			B30	10
B40	10			B8	10
B26	39				
Total round:	462		**463**		443

Table B.9 Actions in passive greedy zeuthen-based strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B22	16	B3	9	B15	9
B56	9	B5	5	B17	10
B2	5	B34	5	B43	50
B13	10	B4	80	B20	4
B19	4	B39	225	B38	125
B37	16	B47	10	B54	10
B27	10	B31	16	B49	18
B53	1	B59	8	B16	1
B29	30	B58	5	B12	10
B50	20	B23	10	B32	10
B52	9	B25	90	B21	10
B46	10			B45	35
B57	60			B41	50
B24	20			B51	18
B42	60			B44	5
B33	15			B28	10
B36	18			B7	40
B48	14			B30	10
B6	15			B8	10
B18	6				
B1	2				
B35	30				
B40	10				
B26	80				
Total round:	**470**		463		435

Table B.10 Actions in coward strategy

Social agent	Round	Economic agent	Round	Environmental agent	Round
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B56	9	B4	80	B2	5
B13	10	B39	225	B43	50
B19	4	B47	10	B50	20
B37	16	B36	18	B20	4
B27	10	B31	16	B45	35
B53	1	B59	8	B38	125
B29	30	B25	90	B54	10
B52	9			B49	18
B46	10			B16	1
B57	60			B12	10
B24	20			B32	10
B42	60			B48	14
B33	15			B51	18
B41	50			B18	6
B6	15			B44	5
B1	2			B58	5
B35	30			B23	10
B7	40			B28	10
B40	10			B26	80
B21	10				
B8	10				
B30	10				
Total round:	452		**461**		455

Table B.11 Actions in coward objective strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B13	10	B56	9	B2	5
B19	4	B4	80	B43	50
B37	16	B39	225	B50	20
B27	10	B48	14	B20	4
B53	1	B31	16	B38	125
B29	30	B59	8	B54	10
B45	35	B28	10	B49	18
B52	9	B26	80	B16	1
B46	10			B41	50
B57	60			B12	10
B24	20			B32	10
B42	60			B51	18
B33	15			B18	6
B36	18			B44	5
B47	10			B58	5
B6	15			B23	10
B1	2			B25	90
B35	30				
B7	40				
B40	10				
B21	10				
B8	10				
B30	10				
Total round:	**456**		**456**		**456**

Table B.12 Actions in coward zeuthen-based strategy

Social agent	**Round**	**Economic agent**	**Round**	**Environmental agent**	**Round**
B5	5	B3	9	B15	9
B22	16	B34	5	B17	10
B56	9	B4	80	B2	5
B13	10	B39	225	B43	50
B19	4	B47	10	B50	20
B37	16	B31	16	B20	4
B27	10	B1	2	B45	35
B53	1	B59	8	B38	125
B29	30	B58	5	B54	10
B52	9	B23	10	B49	18
B46	10	B25	90	B16	1
B57	60			B12	10
B24	20			B32	10
B42	60			B48	14
B33	15			B51	18
B41	50			B18	6
B36	18			B35	30
B6	15			B26	80
B44	5				
B28	10				
B7	40				
B40	10				
B21	10				
B8	10				
B30	10				
Total round	453		**460**		455

CURRICULUM VITAE

PERSONAL INFORMATION

Name Surname :Kerim KOÇ

Date of birth and place :26.02.1991, Niğde

Foreign Languages :English

E-mail :kerimkoc@yildiz.edu.tr

EDUCATION

Degree	Department	University	Date of Graduation
Undergraduate	Civil Engineering	Yıldız Technical University	30/09/2014
High School	-	Yeşilköy Anatolian High School	12/06/2009

WORK EXPERIENCE

Year	Corporation/Institute	Enrollment
2018 - …	Yıldız Technical University	Research Assistant
2017 - 2018	IGA	Technical Office Engineer
2015 - 2016	Gul Proje	Planning Engineer

PUBLISHMENTS

Conference Papers

1. Koç K., Işik Z., (2018). "Role of Construction-associated Parameters in Flood Disaster Management", ACE 13th International Congress On Advances In Civil Engineering, 12-14 September 2018, İzmir/Turkey.

2. Aladağ H., Demirdöğen G., Koç K., Işik Z., (2018). "Game Theory Applications in Construction Management Literature", 5th international Project and Construction Management Conference (IPCMC2018), 16-18 November 2018, Girne/K.K.T.C.