A SYSTEMS APPROACH TO FLOOD RISK MANAGEMENT

The Assessment of Disaster Planning and Resilience with Cognitive Work Analysis

Masters Dissertation

By

AHMET GOKBERK KURMUS

Supervisor: Dr. Guy Walker

Submitted for the qualification of MSc Water and Environmental Management

School of Energy, Geoscience, Infrastructure and Society

Heriot Watt University

August 2017

DECLARATION

I, Ahmet Gokberk Kurmus, confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g. ideas, equations, figures, text, tables, programmes) are properly acknowledged at the point of their use. A full list of the references employed has been included.

Signed: ………………………………………

Date: 09/08/2017

Table of Contents

List of Tables and Figures

Acknowledgements

First and foremost, I am grateful to ALLAH who gave me strength and knowledge to accomplish this duty.

This thesis would not be possible without the encouragement, support, guidance and patience of the following individuals; my sincere supervisor Dr. Guy H. Walker, my esteemed colleague Mr Salih Babagiray, my valuable friends Muhammed Imran Kulat, Sefa Eroglu and Muaz Zaim.

I would like to dedicate this paper to my wife, Betul Kurmus for her support during my life and my master's education, specifically. I am also sincerely thankful to my beloved parents, Yusuf and Serpil.

Lastly, my special gratitude goes to my sponsors, The General Directorate of State Hydraulic Works (DSI), and Ministry of National Education of Turkey for supporting me financially throughout my education in Heriot Watt University.

Abstract

It is widely accepted by scientific communities that flood risk is increasing across the globe. The technical flood defences do not always offer an efficient solution due to the lack of social viewpoint. This realization has initiated a big shift in flood risk management perspective from resistance strategies to resilience strategies.

Introducing more technology to the urban systems increases the complexity of the relations between nature, human and artefacts. The land and the society should not be separated from each other and must be resolved under same assessment technique. In this respect, Cognitive Work Analysis (CWA) offers promising structure to take into account all aspects of the system.

In this study, CWA was applied to the town of Turhal located in Turkey, detected as the fourth highest risky area in current flood risk management plan which is prepared in compliance with the EU Floods Directive, to analyse the system resilience and preparedness against 1 in 500 year flooding event.

By applying CWA, particular recommendations for improving system preparedness and planning were presented. The findings of the assessment present most suitable ways to achieve resilience for the town of Turhal with a platform to analyse the adaptation of town against change.

Glossary of Abbreviations

ADS	Abstraction Decomposition Space
AFAD	Disaster and Emergency Management Authority *(Afet ve Acil Durum Yonetimi Baskanligi)*
AH	Abstraction Hierarchy
CAT	Contextual Activity Template
ConTA	Control Task Analysis
CTA	Cognitive Task Analysis
CWA	Cognitive Work Analysis
DSI	General Directorate of State Hydraulic Works (*Devlet Su Isleri Genel Mudurlugu)*
HTA	Hierarchical Task Analysis
İAADYM	Provincial Disaster and Emergency Directorate (*İl Afet ve Acil Durum Müdürlüğü)*
NGO	Non-governmental Organization
SA	Strategies Analysis
SOCA	Social Organisational & Cooperation Analysis
SRK	Skills-Rules-Knowledge
SYG	General Directorate of Water Management (*Su Yonetimi Genel Mudurlugu)*
WCA	Workers Competency Analysis
WDA	Work Domain Analysis
YFRMP	Yesilirmak Flood Risk Management Plan

Chapter 1

1. Introduction

Nations face with complicated water issues stemming from the impacts of population growth, climate change, and urbanization. Water related topics are now major concern in every part of the globe independent from the development level of countries. Water scarcity, floods and droughts influence regions more intensely than ever before.

It is connected to more than half of the deaths due to "unusual circumstances caused by nature" all over the world every year. The damage caused by the floods affects society in various forms. This devastating natural hazard claimed 85 thousands lives and affected approximately 1.5 billion people between 2000 and 2014 (OFDA & CRED, 2015). Moreover it is estimated that floods caused around $400 billion financial loss in more than 90 countries in that time period. In essence, the impacts of floods have a complex structure. The most prominent impacts of floods seen all over the world are manifested in human life and economy.

Conventional engineering and management processes consider, in general, the hydrologic parameters of floods. The rainfall intensity and time, peak discharges, highest velocities and inundation areas were investigated extensively (Plate, 2002). By the light of these studies flood control strategies were put into action for complete prevention from all floods. Sophisticated flood control measures were taken and enhanced as flood risk rises. It is recognised by the time that defending against all floods is not possible since all technical flood defences have their limits in terms of financial cost and resistance to power of nature. In parallel with the progress in risk studies, flood risk is appreciated by new notions. The interrelations between physical, human-based and constructed systems are commenced to express in flood risk management.

It is acknowledged from the experiences that there is no smooth way of flood risk reduction. Every solution will bring some kind of radical change and economic burden depending on the case. Although flood risk management is complicated and expensive process, it is the key to sustainable development and water management. Therefore, European Union had started legal studies on this issue in 2004 and put into force the "Directive 2007/60 / EC on the Assessment and Management of Flood Risks" on 20 November 2007 (EU, 2007). The objective of the directive is to build a structure focused on assessing and managing flood risks and to reduce the adverse effects of floods on human health, the environment, cultural heritage and economic activities.

In respect to the EU Floods Directive, it can be said that the social and technical aspects should be considered in the flood risk management. The requirements of the new directive highly associate with the resilience which can be, briefly, described as the appropriate response to disturbance (flood waves) and the holistic evaluation of sub-systems (physical, environmental, and social).

Triple consortium was established including Turkey, France and Romania for the implementation of the floods directive in each state's river basins. According to the project EU Floods Directive was enacted as national legislation in Turkey in 2009. Flood preliminary assessments were completed and areas under the risk of flooding had been identified in 2011. Depending on the different recurring flow rates the flooded areas were identified and shown on the maps. Flood hazard and risk maps were prepared in late 2013. Flood risk management plan was revealed in 2015 for Yesilirmak River Basin (SYG, 2015). The total cost of capacity development project for Turkey is €1.800.000 at the end of project which is 31 December 2014 (SYG, 2015, pg. 1-4). The Yesilirmak Flood Risk Management Plan (YFRMP) provide general flood risk management plan for the cities and towns in the catchment. Targets had been set and necessary measures had been summarized to reduce flood damage in the plan.

Cognitive Work Analysis (CWA) is preferred to evaluate the existing management plan and to adopt resilience strategies. The design and analysis abilities of the CWA provides opportunities to take into account the socio-technical dimensions as well as the system adaptation.

1.1. Case Study – Turhal, Tokat, TR

1.1.1. Background

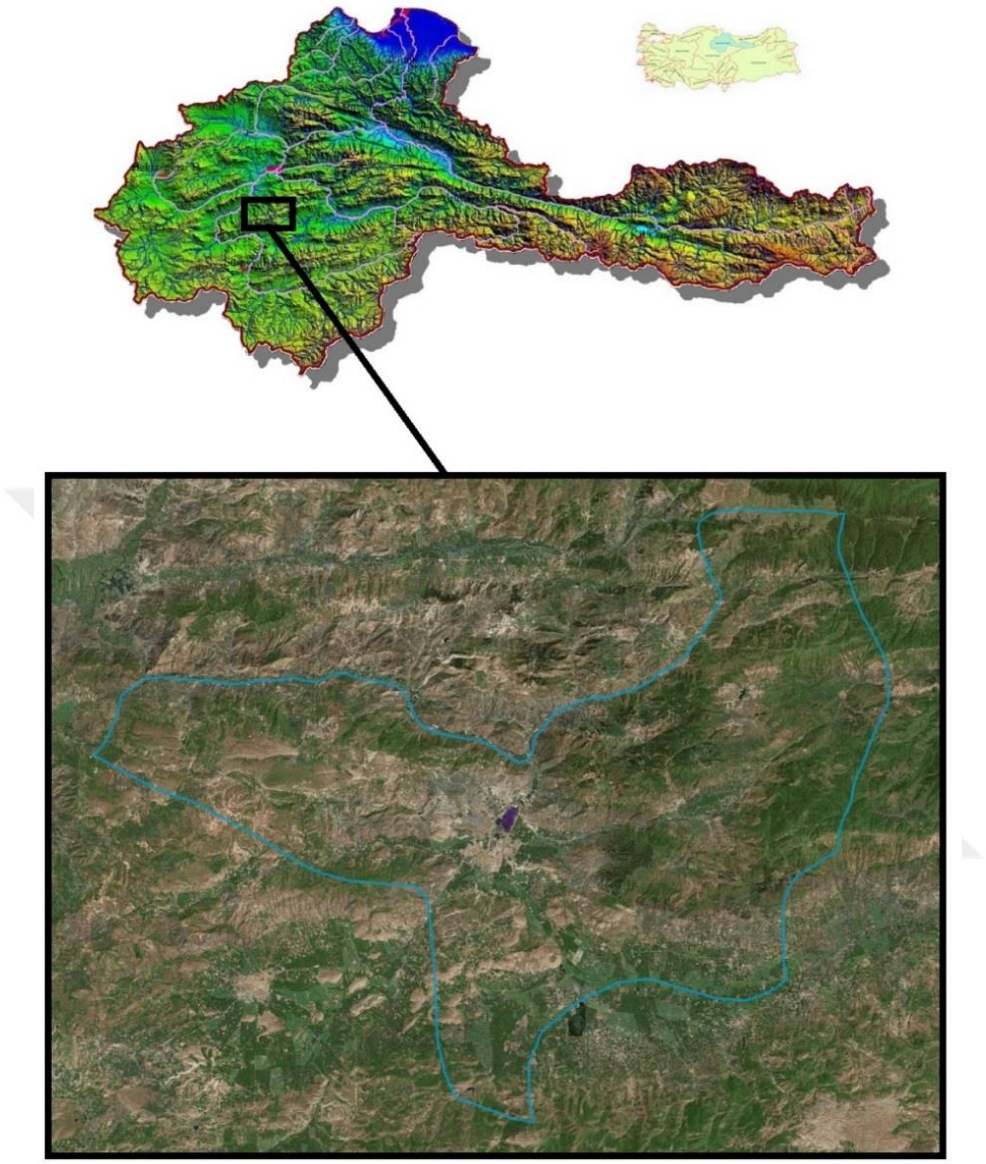


Figure 1-1: Yesilirmak River Basin and the Town of Turhal

The town of Turhal is located in the Yesilirmak River Basin which is one of the 25 basins of Turkey. Yesilirmak giving the name to the catchment means “green river” in the Turkish language and passes through Turhal town and spills into the Black Sea. Yesilırmak River is the second longest river in Turkey with a length of approximately 519 km. The catchment covers approximately 5% of Turkey’s surface area which is taking third largest rainfall amount of the country. After big cities i.e. Samsun and Corum, Turhal has the third largest population that lives within the boundaries of the Yesilirmak Catchment.

With regard to the YFRMP, Turhal is detected as the fourth risky area in the river basin after the historical flood evaluations, hydrometric and hydrological determinations. The town population is currently 80.000 (TUIK, 2016) and 10.000 of the population is expected to be affected by the 1 in 500 year flooding event (SYG, 2015, pg. 16). The 1 in 500 year flooding event stands for the discharge rate of a river that can happen once in 500 years or 0.20% of annual exceedance probability.

1.1.2. Problem

The nature of the problems are stemming from two different contexts. One is originated from the background of the town of Turhal. And the other one is observed in the Yesilirmak Catchment Flood Risk Management Plan (YFRMP).

The problems arising from the physical and constructional background;

- Increasing impermeable layer activities in parallel with increasing urbanization
- Narrowing stream section resulted from the settlement in river bed
- Increasing blockage with uncontrolled waste disposal and natural forestation
- Inadequate cross section of the stream as a result of unauthorised interventions

YFRMP was revealed after huge expenditures and with contribution of a large expert team. Although a noble effort it has some shortcomings;

- The first problem of the YFRMP is that the designers are all from engineering backgrounds. To illustrate this case, the staff consists of eight civil engineers, three meteorology engineers, three geological engineers, three environmental engineers, two agricultural engineers and one topographical engineer (SYG, 2015, pg. iv). This leads YFRMP to be formed by technical point of view.
- The lack of considering flood event in all dimensions; pre-flood, during flood, post-flood stages.
- The stakeholders and beneficiary institutions have been nominated, but organisation chart is structured only for during event stage.
- The flood alert level is stated, however responsible intuitions are not mentioned in an organised form. It is currently unclear how the responders will be organised and how the city will respond to flooding.
- Biggest attention is drawn into the preparedness of cities. On the other hand, smaller towns are not considered sufficiently.

- Non-structural measures have not been mentioned adequately for big cities or even unmentioned for the smaller towns. Furthermore, the combination of structural and non-structural measures for the flooding event has not taken place in any sections of the plan.

1.2. Structure of the Paper

After having identified the general background and the nature of the problem the dissertation will continue as classified below;

Chapter-2 Literature Review: The next section will present the literature review of flood risk assessment and management topics. The definition of risk, flood risk and flood hazard will be discussed and their meanings, in this paper, will be mentioned. The link between the flood risk management and Cognitive Work Analysis (CWA) will be explored at the end of the second chapter.

Chapter-3 Methodology: The use of CWA will be described in detail and the data used in the assessment will be presented.

Chapter-4 Results: The application steps of CWA to the town of Turhal will be introduced with the aid of various figures. And their results will be presented in this chapter.

Chapter-5 Discussions: The results will be reviewed and discussed for the purpose of evaluating existing strategy and searching resilient way of preparing against flood risk.

Chapter-6 Conclusion: The concluding points will be highlighted under consideration of both results and discussions sections.

This dissertation is devoted to explore past experiences, current knowledge and missing points about flood risk management concept. In this contribution, future works will be introduced in the sixth chapter to light the way ahead.

Chapter 2

2. Literature Review

In this chapter, the overall literature that helped to shape this study will be presented. In doing so, first, the main concepts and the definitions of the terms are introduced. Then, systems approach and Cognitive Work Analysis (CWA) are discussed comprehensively. After a summary section, last but not least, aims and objectives are depicted.

2.1. Introducing Main Concepts and Definitions

Introduction part will discuss the definition of concepts forming the basis of this dissertation. The elaboration of different understandings will be assigned to provide profound information source to underpin Cognitive Work Analysis.

2.1.1. Risk

The definition of the risk perspective will inevitably be drawn from the characterisation of risk itself. This term is interpreted differently by different people. Although so many definitions do not make any sense without clarification, it is necessary to define the risk for scientific discussion on the basis of consistency. Traditionally, the risk was regarded as a quantifiable concept. The most commonly used form of risk measurement was obtained from the multiplication of its probabilities and consequences (Helm, 1996). As it is easily noticed from the general definition, the expressions for probability and consequences are abundant in the literature.

$$Risk = Probability\ x\ Consequences$$ *Eq. (2.1)* (Helm, 1996)

Basically, there is no risk where there are no human or property to be affected by the event. Disaster happens when human life and values are lost. A very severe flooding in an unsettled land cannot be classified as catastrophic. In a similar way, the same flooding cannot reach a devastating level in well-prepared town. On the other hand, poorly-prepared regions can be affected adversely by flooding that has much lower severity. The hazard levels in the first and second situations are distinctly higher than that of third case. However, the risk is the highest for third condition since the flooding can become disastrous.

From a real world example, China faces with severe flooding events more frequently than many of the other countries in the world. Two of thirds of the losses in China results from the floods (Li, 2006). Long flooding history accelerates many developments and the country reduces the flood risks remarkably. On the other hand, Saudi Arabia is well-known with its endless deserts and arid climate where no one expects heavy rainfall and flooding. While the probability of occurrence is low the consequences of flooding might be hazardous due to the ignorance of flood risks.

Risk is defined in the insurance literature as a notion that expresses the complete values to be lost according to the probability of danger or the negative consequences of an event (Miller, 1992). Risk can be detected through analysis of historical experiences, analytical procedures, knowledge and prediction. According to Kappes, et al., (2012) risk is the likelihood of a loss that may occur due to damage to people and the environment when an incident occurs in the future.

These simpler expressions of risk have slowly been replaced by more comprehensive identifications comprising hazard, exposure and vulnerability terms.

- *Hazard;* the natural event with its occurrence probability.
- *Exposure;* the humans and the assets in the boundary of the event.
- *Vulnerability;* the tendency to be exposed to the event.

The risk is computed from the production of these three elements recently.

$$Risk = Hazard \ x \ Exposure \ x \ Vulnerability$$ *Eq. (2.2)* (Wisner, et al., 2004)

Even though the second definition of risk has a resemblance to the old one, it gives an opportunity to acknowledge the risk in a wide range, especially for natural disaster science (Birkholz, et al., 2014). The assertion of the terms of exposure and vulnerability initiates greater discussions around their implications which will be discussed in the "Flood Risk" section. As an early conclusion, risk is identified, in this paper, as the sum of the adverse outcomes of a hazardous flooding event that influence both human and non-human dynamics in the town (or any other system under analysis).

2.1.2. Flood

Flooding, a natural phenomenon, has numerous definition. “A flood is a very simple natural phenomenon that occurs when a body of water rises to overflow land that is not normally submerged” (Ward, (1978) cited in Simonovic, (2012)). Although Ward (1978) found flooding as a “very simple natural phenomenon” the recent sophisticated connection between people, social system and natural environment makes it more complex, nowadays. Therefore, De Bruijn, et al., (2007)’s definiton is found more inclusive as “Floods have to be understood as a process rather than a state, and ‘flooding’ as being simply a label applied to one extreme of the time varying pattern of flows in rivers.” More and more links are inserted to those elements as a result of economic development and population growth resulted in breakdown more likely.

2.1.3. Flood Hazard and Flood Risk

After having defined “flooding” and “risk” the two concepts can be brought together to realize “flood hazard” and “flood risk” notions. The definition for hazard took place in United Nations International Strategy for Disaster Reduction (2004) report as “A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources”.

Flooding becomes hazardous if the existing elements of the system cannot cope with the upcoming discharge rates. The negative impact of the flooding can be seen in natural environment and surrounding layout as well as the economy.

Flood risk had been perceived nothing more than the product of the probability of flooding and its impacts; a number of people and properties affected by the event. European Union Floods Directive (2007/60/EC) defines flood risk as “The combination of the probabilities of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated capacity with a flood event” (EU, 2007)

Definition of flood risk and flood hazard (or flood damage) is vital to underpin flood risk assessment and management. In general, the two elements, i.e. probability and consequence, determine the risk. Therefore the risk can increase or decrease depending on the variation of those elements. Civil engineers made a great effort to understand the hydrological characteristics of the flooding event in the past (Sayers, et al., 2002). The frequency and the severity of floods had been investigated by those experts with huge investments. These studies contribute to reduce flood risk to some extent. However, Pielke Jr., (2000) highlights that the damage of flooding has no strong relationship with the hydrological characteristics of floods as a result of physical and social involvement. In respect to this, “The real flood risk stems from the likelihood that a major hazardous event will occur unexpectedly and that it will impact negatively on people and their welfare” (Smith & Ward, 1998)

Evolution of flood risk term follows the path from engineered based pattern to more socially orientated form. The definition of flood risk has been modified and expressed as intersects between hazard, vulnerability and exposure (Wisner, et al., 2004). On most of these terms, there is no consensus (Cutter, et al., 2008). In a very broad extent, the hazard is defined as the probability and magnitude of a flood event that causes loss of life and property, exposure refers to elements or entities that may be adversely affected by a flood impact due to their location within the boundaries of the flood prone area, vulnerability has been ascribed as functions including both physical and socio-economical vulnerability (IPCC, 2012). The greatest debate, without any doubt, is ongoing around the implication of vulnerability term.

Vulnerability concept defined in UN agenda as “Degree of loss (from 0 to 100%) resulting from a potentially damaging phenomenon” (UN, 1992). From a social system point of view, vulnerability is defined by “A set of conditions and processes resulting from physical, social, economic and environmental factors, which increase the susceptibility of a community to the impact of hazards” (UN/ISDR, 2002).

The vulnerability concept involves with social, economic, organizational dimensions along with the local national and regional aspects. It can be observed from the chronologic order that while the early definitions quantify the vulnerability in terms of potential damage, socio-economic parameters have gained more importance in the new century. More recently, Balica, et al., (2009) determined the vulnerability (V) as a three-dimensional space; exposure (E), susceptibility (S) and response capacity (RC). The exposure (E) describes the assets and the community affected by floods independent from the location (to assure direct and indirect effects). The susceptibility (S) is specified by which the system is damaged by floods.

$$Vulnerability = Exposure\ x\ Susceptibility\ x\ Response\ Capacity$$

Eq. (2.3) (Balica, et al., 2009)

2.1.3.1. Increasing Flood Risk

In spite of having identified elements of flood risk in a comprehensive manner, there is a fact that flood frequency and its damage appear to be on the rise. The reasons can be stated as explained below.

Increasing Hazard

The floodplains are found as convenient places to settle allowing development, transportation and other lifelines. The development around the river reduces natural water retention via implementing impermeable layers. Authorities construct dikes and train the river to prevent the settlements from flooding. As a consequence the peak discharges and the velocities of the flooding event become hazardous. This is an experience of increasing hazard locally.

More importantly, the climate change has triggered not only the intensive precipitation but also shift in the seasonal rainfall pattern on the global scale. The extreme events become more severe and uncertain in the 21st century (Adikari & Yoshitani, 2009). The higher probability of occurrence resulted in the higher flood risk.

Increasing Exposure

The dramatic and unbalanced population growth across the globe leads to the increase in exposure. The losses from natural events directly linked to the population who is settled and has values in the affected area. Today the number of belongings of the individuals are getting more and the values are getting higher compared to the former time. Industrial and public entities in the system increase the exposure further.

Increasing Vulnerability

Recent flooding events have shown that current urban systems are vulnerable to disasters, particularly flooding. Vulnerability (V) varies with the dimensions which generate the concept itself. While improving the response capacity reduces the vulnerability, increasing exposure and susceptibility will make an opposite influence.

The exposure (E) defined in the context of vulnerability must be differentiated from the exposure in the "Risk Equation (2.2)". The particular meaning in the vulnerability literature indicates the elements at risk including their elevations, proximities to the river, closeness to inundation areas.

The susceptibility (S) is an indicator related to the technical characteristics of a system and covers awareness and preparedness of individuals and communities. The technical characteristics of the system include many patterns. For instance; the type of the buildings, and the location of pollutant storage tanks and so on. Whilst some technical implementations increases susceptibility (wooden houses, single-storey houses etc.) some might reduce it (stone houses, multi-storey houses etc.). People tend to feel in safe from the flooding since the deployment of improved and sophisticated flood defences. Especially after a few decades of secure settling in a certain region, people start to forget about flood threat completely. The actors' activities are crucial to cope with the flood risk. Therefore, the ignorance of the public increases the susceptibility and vulnerability consequently.

The great emphasis should be put on the response capacity (RC) to acknowledge the vulnerability paradigm. From the vulnerability literature review it is prominently realized that resilience term is adopted on behalf of response capacity (Turner, et al., (2003); Walker, et al., (2004); De Bruijn, (2005)). The reason behind this is the capability and the functionality of the resilience term. According to De Bruijn, et al., (2007) "All definitions of resilience include at least the ability of a system to cope with perturbations." Berkes, (2007) conclude these capabilities in three components: (i) the ability to evaluate hazards holistically i.e. in terms of human-environment coupling relation, (ii) the ability to absorb the disturbance or adapting to it, and (iii) the ability originated from the forward-looking nature to deal with uncertainty. Resilience in the context of this paper will be discussed in detail in further sections.

2.1.4. Flood Risk Assessment

After having definitions of "risk", "floods", "flood risk" and "flood hazard", this section will attempt to highlight the current understanding and changing notions around flood risk assessment. The path which is going through flood risk management should be remembered before beginning to realize the risk assessment concept. Risk assessment considers risk as an input to analyse and introduce the assessment results to risk management so as to deal with the risks.

Risk assessment approaches had been employed to analyse the risk associated with the relatively simple systems during the years after World War 2 (Saidu & Lal, 2015). In risk assessment literature numerous techniques have been developed which can be categorized into three major classes; qualitative, quantitative and hybrid models. These risk analyses consist of three elements; inputs, considerations and outputs. The input phase identifies risks and prioritizes them with historical information and expert judgements. Then, it connects other planning inputs under consideration of interviews and decision tree analysis. Finally, the event is simulated through probabilistic analysis in order to obtain the list of quantified or qualified risks as an output. These approaches are able to analyse the system failure, without any doubt, when justification of the event is sufficiently known. The drawbacks of depending a certain design event can be observed as; the insufficient or unsatisfying theory behind the methods, a need to address performance shaping factors, low validation of methods, unjustified trust in simulators (Carvalho, 2011).

Traditionally failures represent the collapse in system functions. Since the probability of an event cannot be adequately estimated in a real world complexity, failures stand for the opposition of adaptation recently (Leveson, 2004). This idea has also caused a shift in the viewpoint of causation of failure. Whilst conventional methods had seen human as a major actor triggering the accident, recent studies argue that human interaction cannot be separated from the system context. Therefore, the constraints in the system must be clearly identified to assess the risk in complex systems.

Flood risk assessment is an analysis of the most likely adverse effects of flooding (Corriea, et al., 1998). The main objective of assessment of flood risk and its impact is to supply adequate information to decision makers, to maintain environmental characteristics of the area and to prevent damage to commercial and other economic activities in public and private infrastructure.

The risk strategies were conducted to control performance of the system as a result of defining success as a failure-free component and explicitly aiming to eliminate the causes of failures. As a result, in flood risk assessment, risk was expressed as a performance measure of the probability of flood defence that will not fail over a given time interval and under specified environmental conditions (Buijs, et al., 2007). It has been vividly observed from the studies that traditional risk assessment approach is insufficient to link the risks in socio-technical systems where the relationships between human and artefacts are too complex. "A Systems Approach" section will be used to define and connect risks in complex systems in more detailed manner.

2.1.5. Flood Risk Management

It will be useful to appreciate the general risk management title before investigating "flood risk management" thoroughly. Risk management is a discipline that endeavours to reduce the negative impacts of risk to a more acceptable level and a proactive approach that prevents problems before they occur (Rasmussen, 1997). In addition, it ensures that risks are identified before they become hazardous.

In the past, risk management was dealt with as a function of system engineering. System engineering is a multidisciplinary field that aims to realize the design, production and maintenance of complex systems and sub-systems (Birkholz, et al., 2014). Furthermore, it provides all the basic necessary concepts, tools and methods as a single unit for the analysis of these systems. It is inevitable that risk management is also covered by system engineering, but it only includes a certain part of it. Today, risk management is taken from a broader perspective including; determination of acceptable risk levels, elaboration of risk scenarios and measures, analysis of socio-economic cost effectiveness and detection of priorities (Olorunfemi, 2011).

Flood risk management is a complicated process requiring considerable expenditure, appreciation of future drivers of change and time to realize the appropriateness of implemented measures. Hence, it is a solution to the long-term development of the systems.

De Bruijn, et al., (2007) defined flood risk management as "… the combination of all activities that aim at maintaining or improving the ability of a region to cope with peak discharges or extreme rainfall events." In a wider sense Hall, et al., (2003)'s definition is "Flood risk management is the process of data and information gathering, risk assessment, appraisal of options, and making, implementing, and reviewing decisions to reduce, control, accept, or redistribute risks of flooding".

The extensive discussions around flood risk management began relatively late compared to the risk studies (UNDRO, 1991). However, the principles are rapidly evolved with the Dublin Declaration (ACC/ISGWR, 1992) specifying the link between sustainable water management and flood risk management, and shaped with Integrated Water Resource Management report (GWP, 2000). By virtue of these studies, European Union revealed: "Directive 2007/60 / EC on the Assessment and Management of Flood Risks" (EU, 2007). Finally, the World Meteorological Organization (WMO, 2009) promoted integrated flood risk management paradigm which combines different strategies practiced successfully in many regions for many decades.

The primary objective of the flood risk management is; to prevent flood hazards in areas which are exposed to floods and to reduce the construction requirements of flood control facilities that will be more expensive in the future. In addition, flood risk management assists to reduce possible loss of life and property in areas exposed to floods and to significantly reduce the emergency response requirement of the authorities during floods. Despite the fact that this requirement can be reduced with pre-flood protection and prevention efforts, it is not possible to remove it entirely. In respect to this, while the risk of flooding is reduced and prevented, on the one hand, the response capacity for possible floods needs to be constantly improved.

2.1.5.1. Traditional Vision

Traditionally, floods had been evaluated as a one-dimensional hydrological event. As a consequence, previous efforts were commonly put into a land drainage and structural flood defences to cope with the flood menace. Flood control strategies, or in other word resistance strategies, solely focus on prevention from flooding through hazard control measures such as dikes, reservoirs, embankments, dams, river training etc. (Hooijer, et al., 2002). The technically oriented flood protection measures were adopted to manage all floods. This ideology had only concerned about managing heavy rainfall and peak discharges. This perspective leads flood risk management strategies to being essentially based on flood control and flood defence (Hall, et al., 2003). This approach brings an endless need for increasing the capacity of structures to prevent future floods. Furthermore, the whole system is assessed as a monolithic form regardless of changing discharge depths in each section. It is proven from the studies that these structural measures put more economic burden than the actual requirements (Vis, et al., 2003). Saudi and Lal (2015) define these traditional measures as reactive and relief centric.

2.1.5.2. Shift in Perspective

Flooding has been threatening our lives and ecology in all forms and complete prevention has never been possible. The increasing damage of flooding events all over the world has guided experts to concentrate on reducing flood risk issue more intensively. In order to change the approach from reactive to more proactive, a second integrated flood risk management perspective was asserted (GWP, 2000; WMO, 2009). Flood risk management has begun to take the change in physical and socio-economic constraints into account beside the probability and consequence of floods in the consideration of recent risk interpretation.

Integrated flood risk management is an answer to the appropriate division of responsibility question, a balance between structural and non-structural defence options, and an optimisation means for decision-making process. Simonovic, (1999) defined structural measures as "… local protection measures and upstream flood protection measures". Enhancing the river stream capacity via training, retention and stored of flood waves are the major structural defences. Non-structural defences are classified as ensuring proper land use and controlled development, preventing from degradation of floodplain and increasing awareness as well as setting up early warning systems (Corriea, et al., 1998). In this contribution, it does not neglect societal, economic and environmental relationships of flood prone region while recognising sustainable water management and sustainable development. By considering flood risk management in a broader context the social advantages/disadvantages, economic benefits/costs and environmental opportunities/threats can be evaluated in an interdisciplinary, transparent and holistic view.

This mitigation centric paradigm includes preparedness, response and recovery. Integrated flood risk management consists of land use planning, flood warning systems, evacuation plans as well as risk transfer. To ensure prominent management, infrastructures should be maintained before the incident occurs and should be properly operated during the flooding in compliance with the anticipated disaster planning. In addition, communication instruments should be effectively used among the stakeholders to sustain appropriate development before the flooding and for the prevention during the event. This new approach enables decision makers to take into account other development as well as local involvement (Smith, 2013). The transition from focusing on possible flood hazard determination to its consequences in all dimensions enables the decision makers to comprehend what are the riskiest areas and what measures are to be taken. A recently promoted resilience term is adopted to integrated flood risk management strategies in an attempt to bring more insights to the management. By extending the flood risk management strategies beyond the “Risk Equation (2.2)”, it is now possible to appreciate “resilience” pattern in terms of flood risk management.

Figure 2-1: Transition from flood control to flood risk management (Sahin, 2013)

2.1.5.3. Resilience

Resilience must be clearly identified to examine whether the concept is applicable to flood risk management. Resilience is interpreted in different forms by different disciplines. In psychology and psychiatry literature, resilience is understood as “positive adaptation in response to adversity” which can bring transitional and dynamic ideas to risk management literature (Waller, 2001). In the context of ecology, two definitions of resilience are identified. The first definition is introduced as “the ability of a system to return to an earlier equilibrium or development pattern after a disturbance” (Pérez-España & Arreguín-Sánchez, 1999). The second definition is expressed by Holling (1973) as “a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations and state variables”. Consequently, De Bruijn (2004) defined resilience notion for flood risk management perspective as “the ease with which the system, consisting of the socio-economic and physical aspects of the flood-prone area and the river, recovers from floods.”

The first definition in ecology literature is more valid for systems that have static equilibrium state. It is concluded by De Bruijn (2004) that static equilibrium involves with four cases (i) the system does not react at all, (ii) the system reacts but returns to the equilibrium situation, (iii) the system reacts and turns into another stable situation (iv) the system does not return to any stable situation. In contrast, natural systems usually do not follow static equilibrium pattern (Holling, 2000). The dynamism arises from the balance between physical and socio-economic characteristics of the system and the disturbance. The disturbance can be either short-term such as peak discharges that cause flooding or long-term as in the form of climate change or population growth. Holling (1973) indicated resilience adjacent to stability that systems keep their major characteristics besides development rather than having static equilibrium status. Therefore, resilient systems should not collapse nor significantly change after small disturbances.

Avoiding rapid and irreversible change is central concern of flood risk management in such a way as to achieve sustainable long-term path of development.

2.1.5.4. Resilience in Flood Risk Management

The first use of resilience in risk literature goes back to the definition of vulnerability (i.e. Equation 2.3). It can be concluded from the equations (i.e. Equation (2.1), (2.2), (2.3)) that the most active term is “resilience” among all defined concepts. Therefore, basically, the innovative strategies towards flood risk management are called “resilience strategies”. Alternatively explored resilient concept is capable to deal with flood risk in more enhanced form resulting from assessing risk in its both factors.

Resistance strategies strive to reach highest discharge which will not cause floods. Therefore, they aim at river training, construction of levees and retention by reservoirs as conventional flood control methods do (Merz, et al., 2010). In contrast, resilience strategies can be defined as strategies that try to increase system capability via education and preparedness, to accelerate recovery rates by insurance and to adopt land use through regulations. Resilience strategies consider all elements of the system that is highly likely affected before, during and after the floods while resistance strategies targeting single discharge event. This leads to change in perspective of flood risk management from “fighting floods” to “living with floods” (ICE, 2001).

Resilient models combine structural and non-structural measures to not only mitigate flood hazard but to reduce the adverse consequences of flooding. These steps should be followed by appropriate emergency strategies and recovery planning. As a result of conducting resilience strategies to flood risk management process, it is expected to improve urban development, to remove mismatches between needs and response and to introduce governance structure as an opportunity rather than an obstacle.

The purposes of the resilient strategies are highlighted below;

- Determination of methods for spreading timely and reliable warnings by early detection of floods,
- Prevention of injury and loss of life due to floods,
- Reducing the future damage to the public and private property which may be caused by flood and flood related reasons,
- The initiation of post-flood actions,
- Development of community awareness related to flood disaster.

As a consequence of all this, it is aimed to achieve;

- Sustainable development,
- The maximum benefit from flood plains,
- Life and property losses reduction,
- Natural, historical and cultural heritage protection.

After introducing "Integrated Flood Risk Management" and "resilience" concepts it is argued that resilience is able to meet the requirements of integrated flood risk management. On the other hand, resilience is not an instrument to achieve all of these goals by itself, rather, it represents an idea that creates the most appropriate strategy. In this regard, Mileti, (1999) and Simonovic, (2011) strongly recommend systems approach to flood risk management to acquire a global perspective.

2.2. Systems Approach

The idea behind the systems approach, in the most general sense, is to connect all complex elements with strong links while recognising the system superiority compared to the sum of its parts.

> *"Systems theory is based on the definition of a system as a collection of various structural and non-structural elements that are connected and organized in a way to achieve some specific objective through the control and distribution of material resources, energy, and information."* (Simonovic, 2012)

In terms of flood risk management, systems approach offers a wide variety of opportunities to take into account all constraints and capabilities of the system. Additionally, the resources allocation and information distribution are ensured in this theory. This does not only allow for introducing flood risk reduction measures but also might increase system resilience against flooding. Resolving the system under consideration of systems approach will reveal the missing points between analysis and design.

2.2.1. Socio-Technical System

Every system is threatened by risks either external disturbances or the internal failures. Whilst hurricanes, earthquakes, tsunamis, floods threaten the cities externally, internal threats are terrorism, explosions, fires and so on. Some of the world's biggest cities; Istanbul (Turkey), Cairo (Egypt), Damascus (Syria), etc., have not lost their importance despite leaving the second millennium behind with continuous occupancy and ever-repeating calamities. While some others have relatively less significance; Granada (Spain), Bukhara (Uzbekistan), Kaifeng (China), or completely wiped out; Pompei (Italy), Helike (Greece). The reality behind the durability of the cities is their resilience, inarguably. Resilience appears either withstand the shocks or the adaptation to disturbances. According to Pielke Jr., (2000) towns should be considered as complex socio-technical systems which include both human, artefacts and their endless relationship. That socio-technical system has its own constraints (physical, social and environmental) and actors which must be included in the analysis.

2.2.2. System Analysis in Flood Management

System's operations can be analysed in formative, descriptive, and normative way. Specifically, Cognitive Work Analysis–CWA (Vicente, 1999), Cognitive Task Analysis–CTA (Schraagen, et al., 2000) and Hierarchical Task Analysis–HTA (Shepherd, 2001) are some of the most common techniques.

The normative approach describes how the system process "should be" and are well suited to domains when focusing on the solution and output. As a consequence, they supply an information for linear analysis i.e. "how the system currently performs and how the system should perform" (Jenkins, et al., 2008a). The admission of "one best way" to reach the goal is the basic foundation of this approach. Normative methods usually cannot be applied to unstable and non-repeatable systems. In contrast, real situations are typically unstable and hard to predict.

Another point of view is formative approach examining the current state of a system from an angle that does not include any value judgment (Fidel, et al., 2004). As it is known from the literature that formative analysis properly fitted to systems that are constantly changing and difficult to predict. By this reason, these systems require continuous adaptation over the process. Formative approaches are more applicable to the systems which are generally non-linear. They have been dealing with "what can happen" since they characterise initial conditions to assist adaptation of the system.

> *"Whereas a normative approach to establishing a reach envelope prescribes specific movements that should be used to reach, a formative approach identifies the requirements that must be met in order to reach safely and effectively"* (Vicente, 1999).

The dynamic nature of formative approaches can be well suited to flood risk management domain since it recognises the changes in the system elements, particularly the land and the society. In regard to Vicente, (1999)'s statement above, the adaptive capacity of a system can be sampled through a formative evaluation as the requirements are identified and met during the process. The interrelated non-linear factors between the Earth's physical system, the human systems and the built environment systems can be analysed with a dynamic formative model.

2.2.3. Cognitive Work Analysis

In the early 1960s, a group of researchers were established at the Electronics Department of Risø National Laboratory to analyse the reliability of a nuclear equipment and instrumentation in Denmark. They started to design hardware systems to predict accident risk in their research facilities. On the other hand, they explored that in spite of designing reliable hardware systems accidents do occur. Then they fundamentally collected empirical data on the human factors and the environment that they imposed to. As a result of evaluating 100 cases in the air transportation domain and 29 cases in the nuclear domain, they found that human error accounted for three-quarters of these accidents (Naikar, 2011). They pointed out that human error directly depends on the exposed environment of workers. Therefore, Risø organisation began to focus on human-machine reliability rather than solely machine reliability in the 1970s. Finally, CWA was developed and published in 1986 by Jens Rasmussen.

CWA has a promising framework that has been applying to numerous complex domains including; team design (Naikar, et al., 2003), design and evaluation of interfaces (Pejtersen & Rasmussen, (1997), Vicente, (1999), Vicente, (1995)); system modelling (Hajdukiewicz, 1998), automation (Mazaeva & Bisantz, 2007), error management strategy design (Naikar & Saunders, 2003) training needs analysis (Naikar & Sanderson, 1999) and command and control systems (Chin, et al., 1999). These activities have adapted to studies in various of fields including; patient monitoring (Sanderson, et al., 2004), human information behaviour using information technologies and knowledge management (Fidel, et al., (2004); Pejtersen, et al., (2001), Katapol, (2006)), road transport (Salmon, 2007), military command and control (Jenkins et al. 2008 a,b), aviation (Naikar & Sanderson, 2001), nuclear power (Olsson & Lee, 1994), air traffic control (Ahlstrom, 2005), petrochemical (Jamieson & Vicente, 2001), hydropower (Memesevic, et al., 2005), naval (Bisantz, 2003) and health care (Watson & Sanderson, 2007). Surprisingly, even though it is designed to analyse complex socio-technical systems, the application of CWA to urban systems is very less compared to other domains.

2.2.4. The Benefits of Cognitive Work Analysis

Socio-technical systems' overall functionality is based on communication and cooperation. The objective of CWA is to map out the capabilities and constraints of large-scale systems so as to design and analyse the social and technical aspects. As a systems approach, CWA projects the structure of the system including the work domain, the allocation of roles, the collaboration that assists transactions in society and the strategies which will be executed (Gavan, 2013).

After changing the nature of the urban areas, it requires a comprehensive approach to analyse the system mechanism. An approach that is capable to define failure and success terms as it is found in the recent risk assessment literature. Jenkins, et al., (2010) has defined CWA as a socio-technical system approach in terms of the constraints on actors. The constraints are identified as the behaviours that are acceptable or possible (Rasmussen, et al., 1994), the expression coincides with the recently defined failure and success terms in risk literature. Therefore, CWA is chosen to cope with real world challenges and complexity.

The development and the analysis of socio-technical systems can be structured with its well-designed framework. CWA can examine the system resilience as well as evaluate the preparedness of disaster planning. Essentially, CWA considers the constraints affecting the system performance within the environment that comes into existence. Formative nature of Cognitive Work Analysis (CWA) is found useful since flooding has become more difficult to predict as a result of climate change, population and development growth. The command and control domain in CWA corresponds to flood risk since both of them are inherently unpredictable. Even more important than that the system adaptation of CWA allows for the implementation of resilient strategies. CWA will not judge how the system is laid out nor try to establish a new system. Instead, it will try to find out how the town is prepared for the upcoming disaster and how adaptation should be maintained in a resilient way.

2.3. Summary

The current knowledge around the flood risk management studies points out the general concerns after examining the past management experiences. This section is dedicated to link these issues to our case study and then show the implementation problems of EU Floods Directive. Turhal's flood risk management plan (YFRMP) was prepared in compliance with the EU Floods Directive. On the other hand, the issues coming to light after reviewing the literature can be still found in existing flood risk management strategy.

First of all, the involvement and the awareness of public is crucial to reduce flood risks in socio-technical systems. The last flooding event happened in 2005 in the town of Turhal and did not have a big impact on the society as well as the economy. This situation leads to the omission and relief among the people. Hence, people tend to ignore flood risk currently. However, 1 in 500 year flooding can be devastating for the town since it is forecasted to inundate almost half of the town's land and to affect one of eight of the population. In addition, Turhal's economy was heavily based on agriculture and livestock breeding in early the 2000s and rapidly changed to commercial activity in ten years (TUIK, 2013). It is an indication of increasing values and entities in the town which increases the town's exposure and vulnerability to floods.

Secondly, the flooding event is not evaluated with its all dimensions including pre, during and post flood strategies. The spatial and temporal distribution of actions plays a major role to achieve resilience in flood risk management plan. The emergency response of the city is not identified explicitly.

Last but not least, YFRMP is highly shaped by engineering background and far away from the social viewpoint. It can be observed from the "Measures for Mitigating Flood Risk" section in the plan (SYG, 2015, pg. 46) that the offered flood management measure is structural *(see. Appendix-A)*. Non-structural measures found in integrated flood risk management literature such as improved early warning systems, risk transfer, communication and cooperation skills were not specified adequately in YFRMP.

Flood risk management has been investigating seriously by worldwide organisations and expert teams. The concept has evolved with the new notions and now it assists to manage flood risks more comprehensively. However, the issue arises from the implementation of these new ideas. Although innovative arguments have been inserted to flood risk management title, the method while achieving these goals is not mentioned explicitly. The author of this paper heavily concerned about the gap between the directive and the application.

As a systems approach Cognitive Work Analysis (CWA) is preferred at this stage to represent the resilient way of thinking of flood risk management procedure. The capabilities of CWA might be a key to resolve the problems originated from misapplications.

2.4. Aims and Objectives

The overall reason to focus on CWA, in this paper, is to achieve resilience via assessing the general risk management strategy and flood risk management specifically. In addition, insights of the emergency planning and preparedness of the town of Turhal can be observed in the more detailed format through CWA. By adopting CWA, it is also desired to explore the gap between design and analysis for the Yesilirmak River Basin Flood Risk Management Plan (YFRMP).

By using CWA, it is expected to unearth the answer to the following questions. The reason behind asking these research questions is to explore solutions for issues in the current management plan and achieve resilience by the light of recommendations.

- How can the issues in the Turhal’s current management plan be resolved by Cognitive Work Analysis?
- What holistic and multi-faced recommendations can be built to improve Turhal’s resilience in consideration of Cognitive Work Analysis?

Chapter 3

3. Methodology

In this chapter, the stages of CWA will be explained and the difference between CWA and traditional approaches will be introduced. This will be followed by the presentation of the data that will be used to populate CWA in next chapter.

3.1. Elements of Cognitive Work Analysis

CWA consists of five phases;

-*Work Domain Analysis (WDA)*

-*Control Task Analysis (ConTA)*

-*Strategies Analysis (SA)*

-*Social Organisation & Cooperation Analysis (SOCA)*

-*Worker Competencies Analysis (WCA)*

Each stage has its own methodology and product. These phases with their products are laid out by Salmon, et al. (2010) displayed in Figure 3-1.

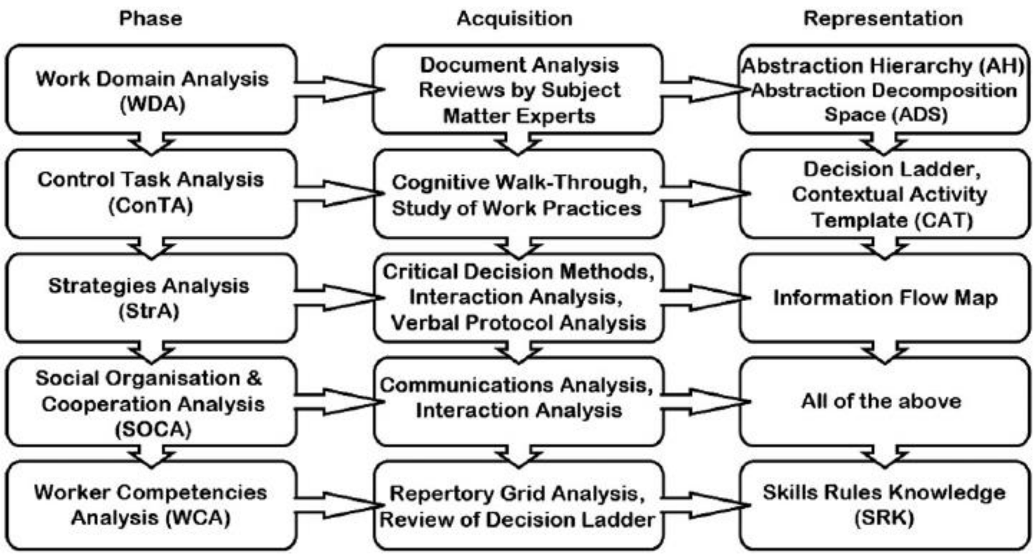


Figure 3-1: Cognitive Work Analysis phases with methods and their products (Salmon, et al., 2010)

3.1.1. Stage 1 – Work Domain Analysis (WDA)

Work domain is ascribed as an intentional-functional-physical environment where the work is accomplished. WDA specifies the capabilities and systemic constraints shaping the activity that are imposed to the actions of the actors in the system (Vicente, 1999). The basis of the WDA is respectively asking questions on the purposes and constraints: Why does the system exist? How does it work? And finally, what does support those functions? (Jenkins, et al., 2008a)

The abstraction hierarchy (AH) and abstraction decomposition space (ADS) are the products of WDA. Five levels of abstractions are provided by Naikar, et al., (2005) as it is presented in the Figure 3-2. Abstraction hierarchy allows the analysts to describe the system in actor and time independent manner. In modelling a system this way WDA outlines the levels of functional abstraction and different degrees of decomposition.

	Level of Abstraction	Description (Naikar, et al., 2005)
1.	Functional Purpose / Overall Purpose	For what reason does the system exist? What is the end state?
2.	Value and Priority Measures	What criteria can be used to judge whether the work system is achieving its purposes? What is the outcome?
3.	Purpose Related Functions	What functions are required to achieve the purposes of the work system? What are the effects?
4.	Object Related Processes	What can the physical objects in the work system do or afford? What are the activities?
5.	Physical Objects	What are the concrete physical objects or resources in the system?

Figure 3-2: Five levels of abstraction that can be applied to any system ***(Naikar, et al., 2005)***

3.1.1.1. Abstraction Hierarchy (AH)

The product of the WDA, namely Abstraction Hierarchy (AH) is a flexible approach that can propagate the small changes to levels above. Each level of abstraction is linked with means-ends lines to represent a visually traceable model. AH levels and their roles are explained in the following section.

The following patterns of the system must be clearly identified to construct abstraction hierarchies.

- Physical Objects
- Functional Purpose / Overall Purpose
- Values and Priority Measures
- Purpose Related Functions
- Object Related Processes

After defining all steps, the nodes are allocated for each five level of abstraction according to the statements above. Once the nodes take their places, they are linked through means-ends relations those likely to be in place prior to and at the onset of a flood (Beevers, et al., 2016). Abstraction Hierarchy is modelled through what-why-how question sequence. The creation of nodes starts with asking question 'what it does'. The answer gives the corresponding node. The level above is the answer of 'why the related node is needed'. The nodes are linked to their reasons. The answer of question 'how this can be achieved' is located directly above to all of the nodes.

3.1.1.2. Abstraction Decomposition Space (ADS)

Vicente (1999) provided a tool to represent WDA called Abstraction Decomposition Space (ADS). In a very basic form, ADS is a product that uses both Abstraction Hierarchy and the system components. ADS is laid out as two-dimensional matrix as it is seen in Figure 3-3. While vertical dimension consists of abstraction hierarchy levels, the horizontal dimension is represented by the system parts. This design makes ADS capable of dividing AH into three or more individual components.

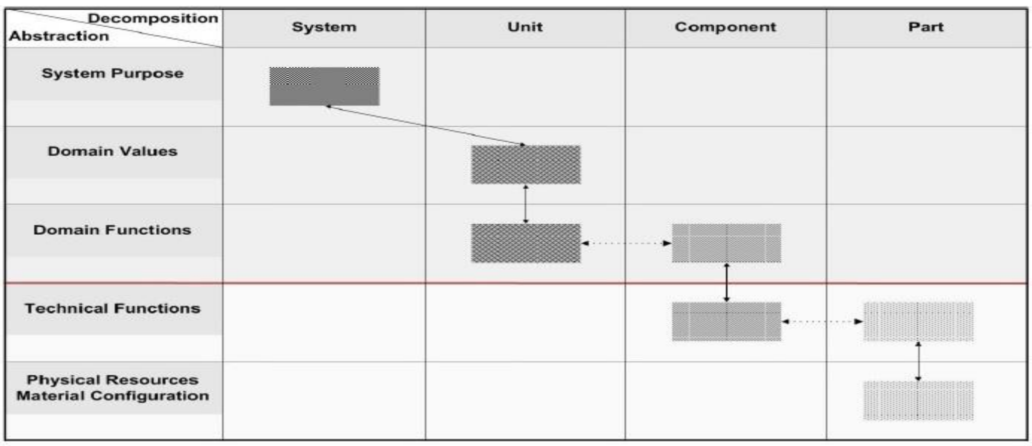


Figure 3-3: The standard two dimensional format of abstraction decomposition space *(Gavan, 2013)*

3.1.2. Stage 2 – Control Task Analysis (ConTA)

Control Task Analysis (ConTA) is the second phase of Cognitive Work Analysis that was inserted by Naikar, et al., (2005). To illustrate this case, this organisational stage was not discussed in Vicente's (1999) study. It is the phase that can be called activity analysis between the work domain analysis and cognitive activity analysis. Therefore, ConTA does not identify the actors explicitly while addressing the constraints on activity. The inputs and the ultimate goals of the system are specified in this middle process. This phase of CWA is found useful in that it considers all situations including; preparedness before the event, response to flooding and recovery after the event. Contextual Activity Template (CAT) is a means of representing ConTA that was provided by Naikar, et al., (2006).

3.1.3. Stage 3 – Strategies Analysis (SA)

This phase of Cognitive Work Analysis points out the constraints imposed by strategies while performing an activity. While the product of the ConTA describes 'what can be done' Strategies Analysis (SA) identifies the process that expresses 'how this task can be done' (Salmon, et al., 2010). SA focuses on the 'black boxes' that are left by ConTA (Jenkins, et al., 2008a). SA is found as the closest phase to hierarchical task analysis's (HTA) goal decomposition and plans component by Salmon, et al., (2010).

3.1.4. Stage 4 – Social Organisational & Cooperation Analysis (SOCA)

The fourth phase of CWA, Social Organisational & Cooperation Analysis (SOCA) explains how the work is distributed, coordinated and managed (Gavan, 2013). The spatial and temporal distribution of the work between the teams is identified by SOCA. The collaboration and coordination of teams take place in cooperation analysis in SOCA. The interaction between social and technical factors is determined explicitly in this phase of CWA. Therefore, SOCA also deals with the modelling of constraints on activities that shape the social organization. The planning of organisational structures for different situations is not primarily objective of SOCA instead it aims to identify the work allocation distribution and social organisation. By this reason, Jenkins, et al., (2008a) highlights that "SOCA explicitly aims to support flexibility and adaptation in organisations".

3.1.5. Stage 5 – Worker Competencies Analysis (WCA)

The final phase of CWA provides a tool to assign the correct actor to accomplish the action. WCA uses Rasmussen, et al., (1994)'s Skills-Rules-Knowledge (SRK) taxonomy. The ideal actor is chosen after employing SRK taxonomy (Vicente, 1999). WCA constitutes the last step to achieve a successful outcome by identifying competencies.

3.2. Cognitive Work Analysis Strengths & Weaknesses

Cognitive systems are criticized by "point-of-view" and "scale-up" problems. These are common problems when large-scale systems analysed from a single point of view (Gavan, 2013). This leads to the lack of understanding of the interdependencies between macro and micro views. As a result, the opportunist alterations and movements cannot be adopted between sub-systems. An analytic and design efforts are discussed by Naikar & Sanderson, (2001) to overcome the point of view problem yet could not offer a holistic solution. These efforts eliminate the issues locally but could not respond to new design implementations. To prevent the system performance from unintended interactions CWA adopts Abstraction Decomposition Space (ADS) to examine the selected elements of the system in detail. The scale-up problem of CWA is resolved through the ADS which represents the whole system while enabling the traceability of the work levels.

The framework of the CWA is generally found time-consuming and labour intensive. Organisations or designers, most commonly, prefers tools which are simple to evaluate the system and cheap to run the model. In contrast, the unique capacity of CWA is developed to deal with a large amount of data that causes re-evaluation and modification more expensive and time-consuming. Therefore, small research groups often prefer small sample sizes to avoid these processes. Jamieson et al., (2003) analyse different design examples and try to detect obstacles so as to complete the project in time and budget efficient form. As it is developed for large and complex systems CWA is not always appropriate for small scale analysis. On the other hand, it elicits novel structure to cope with extensive systems.

The main stream criticism is based on that the studies have mostly been giving emphasis to WDA which is the first phase of CWA and neglect the other phases. Several authors has made an attempt to extend the analysis beyond the WDA (Naikar, et al., (2002) Sanderson, et al., (1999); Sanderson, (2000)). This is pointed out by Jenkins, et al., (2008b) to illustrate the connections between the five phases.

Other concern which is frequently expressed in the literature is the gap between analysis and design. Jenkins, et al., (2008b) endeavour to narrow it in human factors. The significance of Social Organisation & Cooperation Analysis (SOCA) is highlighted in that paper and command control microworld example is used to develop the adaptive interface. Jamieson et al., (2003) efforts also assist to overcome the gap by favour of detecting unanticipated obstacles.

CWA seems highly complicated and occasionally requires additional elements (i.e. Vicente, (2002) ecological interface) to tackle with the systems other than those led to its development. Even though the flexible framework let the analysts to integrate additional patterns they must be aware of different disciplines' literatures to sufficiently justify their study.

3.3. CWA vs Traditional Approaches

Traditionally, systems were evaluated as simple, linear domains. Therefore, they assess the systems from a single viewpoint. However, flood risk management requires complex design and thinking. CWA gives us an opportunity to consider all system elements in one analysis. Focusing on both social and technical constraints provides reliable expressions for the flood risk management plan.

One of the most beneficial ability of CWA is to test system resilience against disturbances. This is a recognition of adaptive design philosophy. By this way, CWA is not only aiming to enhance response capacity but also supports adaptive capacity. Whereas traditionally the system adaptation was not represented in flood risk management plans.

Conventional flood risk management approaches heavily focus on dealing with flood waves and peak discharges by technical flood measures. However, CWA deploys non-structural defences as well as involving the society into the management plan. CWA also provides tools that cannot be found in traditional models in order to understand a system in more detail. The new tools show organisation and cooperation skills of the system by using communication instruments effectively.

3.4. Adaptation of CWA for Case Study

CWA will examine the town of Turhal's resilience and preparedness against 1 in 500 year flooding. The way of employing CWA can be done either manually or with an aid of software. CWA will be adopted by means of visual diagrams and figures in this dissertation since current versions of software more suitable for business management purposes. Another reason for manual application is to display the link between steps and end the assessment where it is found appropriate.

3.4.1. Data Used in the Assessment

The data used in the analysis can be called "secondary" which is obtained from the Yesilirmak Flood Risk Management Plan.

- Flood propagation areas and the risk parameters are extracted from the YFRMP (SYG, 2015, pg. 158).
- The flood control measures in YFRMP are used in some part of the assessment to evaluate the effectiveness against flooding event and suggest further improvements.
- The agencies found in YFRMP keep their presence, however, will be organised under assessment of CWA (SYG, 2015, pg. 169)

3.4.2. The System Boundary

Three different methods have been studied, in YFRMP, to determine the future floods and their spreading areas including; Exzeco method, water level enhancement method and alluvial deposition method. Since it is not directly dependent on the accuracy of the elevation data alluvial deposition method was preferred (SYG, 2015, pg.25).

1 in 50 years return period	1 in 100 years return period	1 in 500 years return period

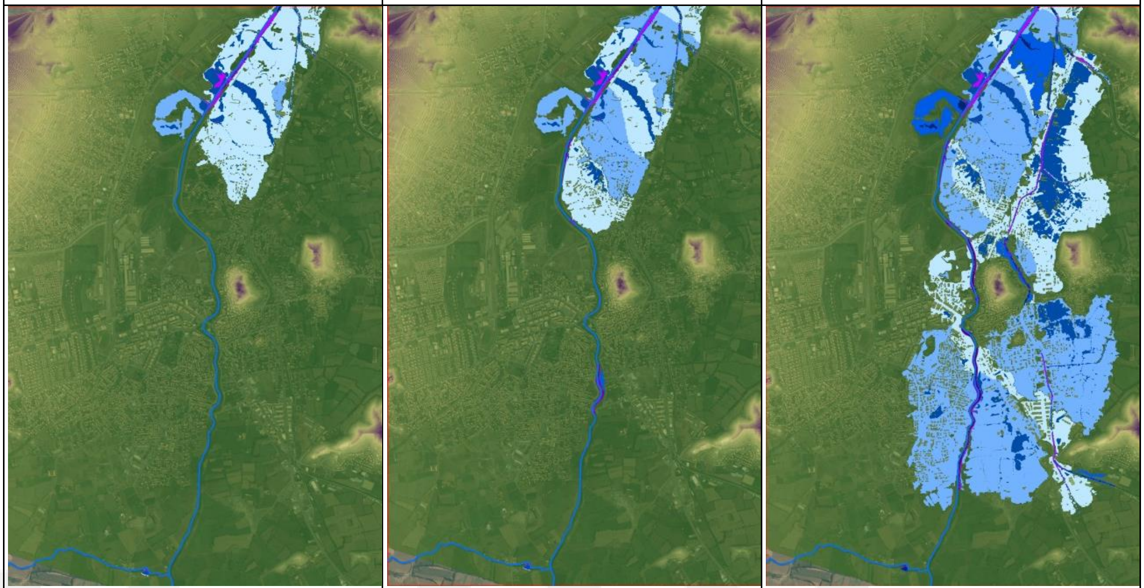


Figure 3-4: Flood maps for the town of Turhal for 50, 100 and 500 year flooding events prepared via Alluvial Deposition Method *(SYG, 2015)*

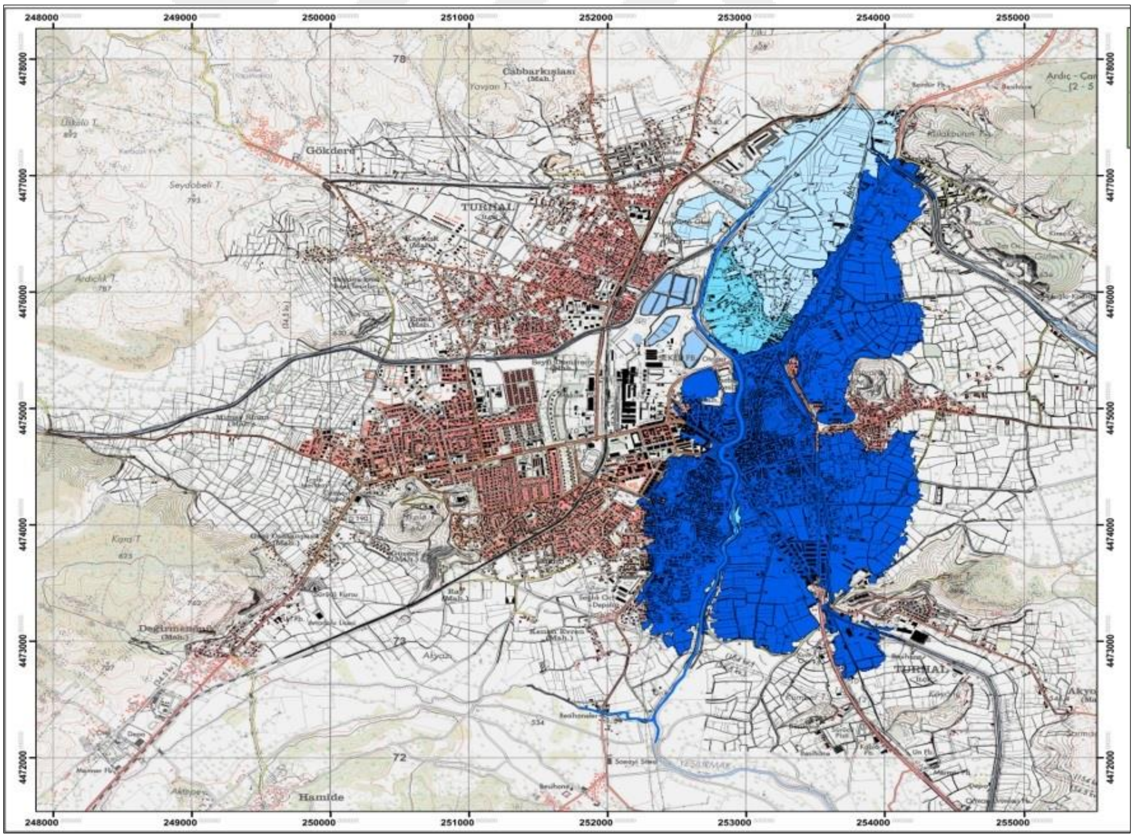


Figure 3-5: Demonstration of flooded areas for three different return period in one map for town of Turhal *(1 in 500 year flooded boundary comprises both 1 in 50 and 1 in 100 year inundated zones)*

Chapter 4

4. Results

The framework of Cognitive Work Analysis (CWA) will be underpinned to four stages and structured for the town of Turhal. The results of each step will be presented in this chapter.

4.1. Work Domain Analysis Results

4.1.1. Abstraction Hierarchy

Two separate AHs are considered for the town of Turhal, in this paper, to provide more insights towards the capabilities of the system. First, the physical objects that will be affected by the flood waves were populated and modelled in the Abstraction Hierarchy – I in Figure 4-2. The second AH was developed to draw attention to the both type of flood defences (i.e. structural and non-structural) in order to present a tool that will be used in Turhal's disaster preparedness plan. That AH is presented as Abstraction Hierarchy – II and displayed in Figure 4-3. Abstraction Hierarchy I and II are populated according to steps that are specified in Naikar, et al., (2005)'s study.

Step 1 - Physical Objects

Physical objects are those falling within the borders of 1 in 500 year flooding event. The extent of the indicated flood is obtained from the related section to Turhal town in YFRMP. Physical objects level forms the bottom layer abstraction hierarchy.

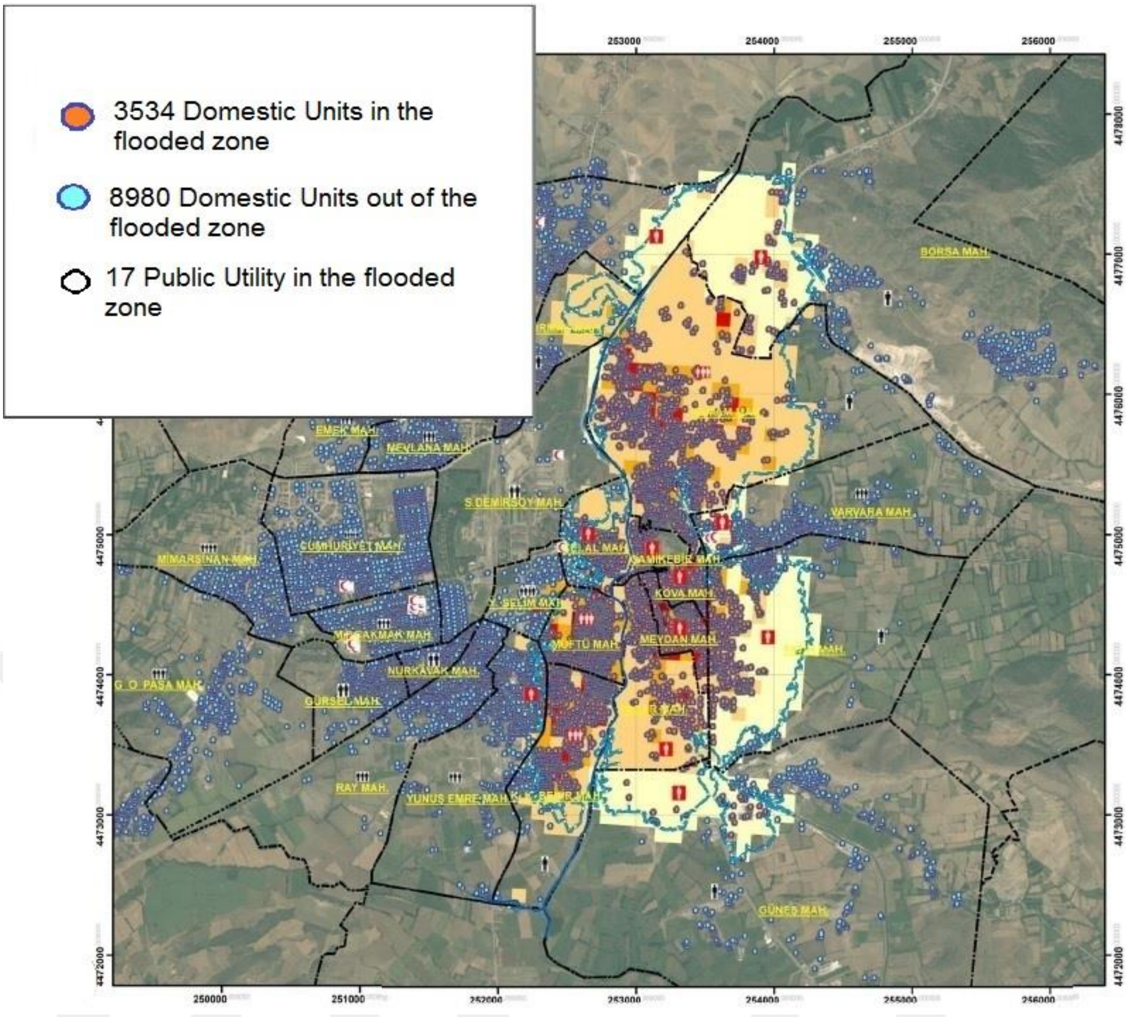


Figure 4-1: Properties at risk with 1 in 500 year flooding event (SYG, 2015)

Step 2 - Functional Purpose / Overall Purpose

The top level of AH is Functional Purpose or Overall Purpose. As the name implies, the primary objectives of any system are stated in this level.

After combining the overall purposes of Abstraction Hierarchy – I and Abstraction Hierarchy – II, the system's fundamental reasons for being for the town of Turhal is defined as;

i. Meet shelter needs / accommodation
ii. Protect cultural heritage
iii. Provide safe and secure conditions
iv. Support economic activity
v. Support freedom of movement
vi. Provide infrastructure
vii. Response to Flooding

Step 3 - Values and Priority Measures

The second tier of the AH (from up to down) is represented by values and priority measures after functional purposes. This layer is of particular importance in many aspects. It plays a critical role in conveying the purposes to level above. Values and priority measures inform the analysts about how vulnerable the system is. Since it provides measurable values analysts can readily compare and step into action. Using two different AH in this paper will provide a solid tool that comprises both the defences existing in the system (AH- II) and the units affecting the capabilities of the system (AH- I).

Step 4 - Purpose Related Functions

The transition phase namely, purpose related function, is placed in the middle of the AH. Basically, this level of abstraction illustrates the functions of services in AH- I and missions in AH- II.

Step 5 - Object Related Processes

Object related processes provide the purposes of the physical objects that are defined in the first step. This layer enables analysts to comprehend the differentiation between the system purposes and object purposes. Limitations and capabilities of the objects in the system can be described with object related process tier.

The aim of populating AH in this dissertation is to display the objects in the boundary and the constraints that they are subjected in the work domain (i.e. town of Turhal). The reason for demonstrating the units outside of the flooded area in Figure 4-1 is to comprehend the system connections and to identify opportunities. The system functionality can be examined via changing or removing nodes in the AH and by way of designing different allocations.

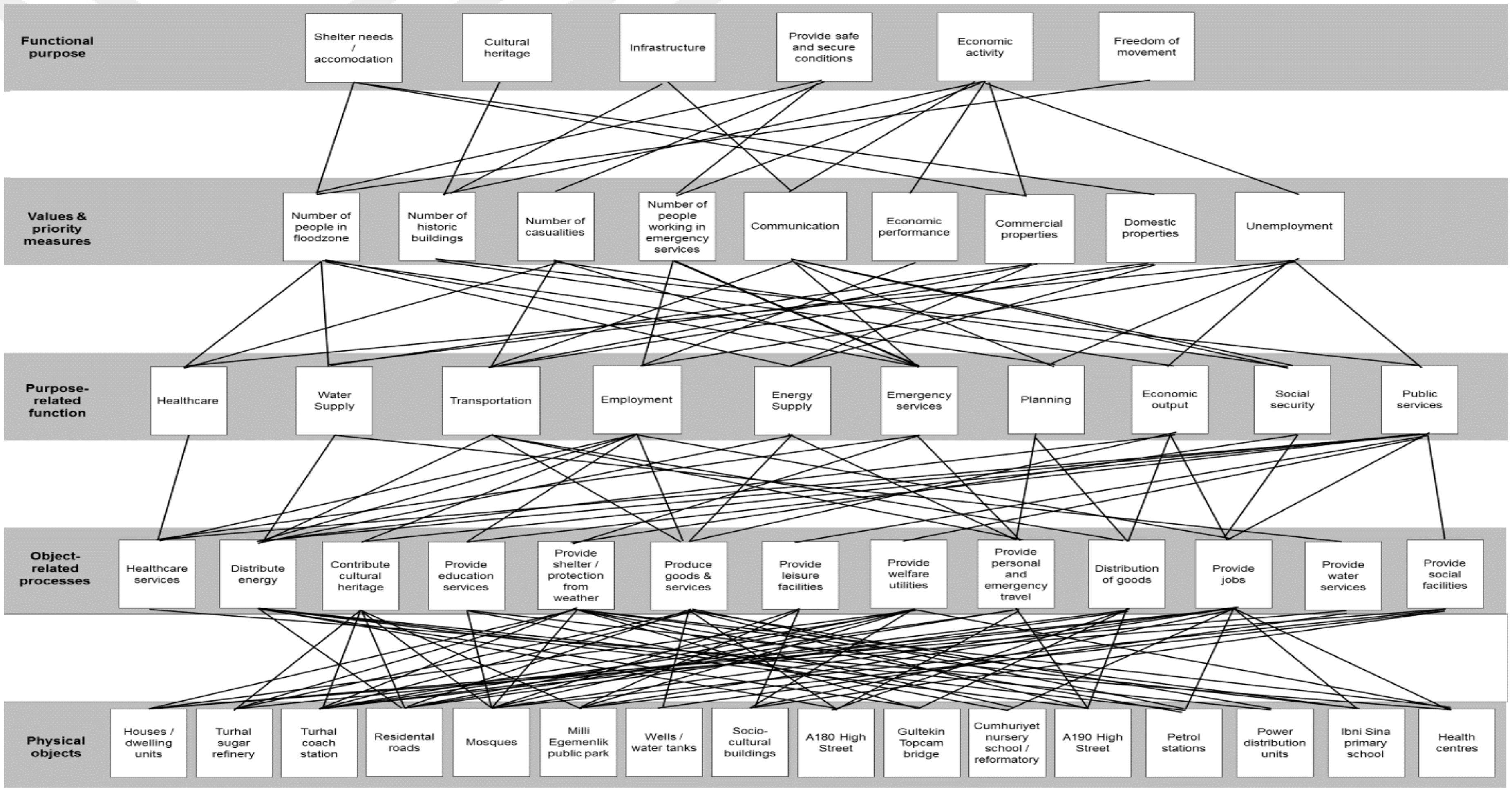


Figure 4-2: Abstraction Hierarchy for the town of Turhal. Physical objects include the elements that exist in the boundaries of a 1:500 year flood event

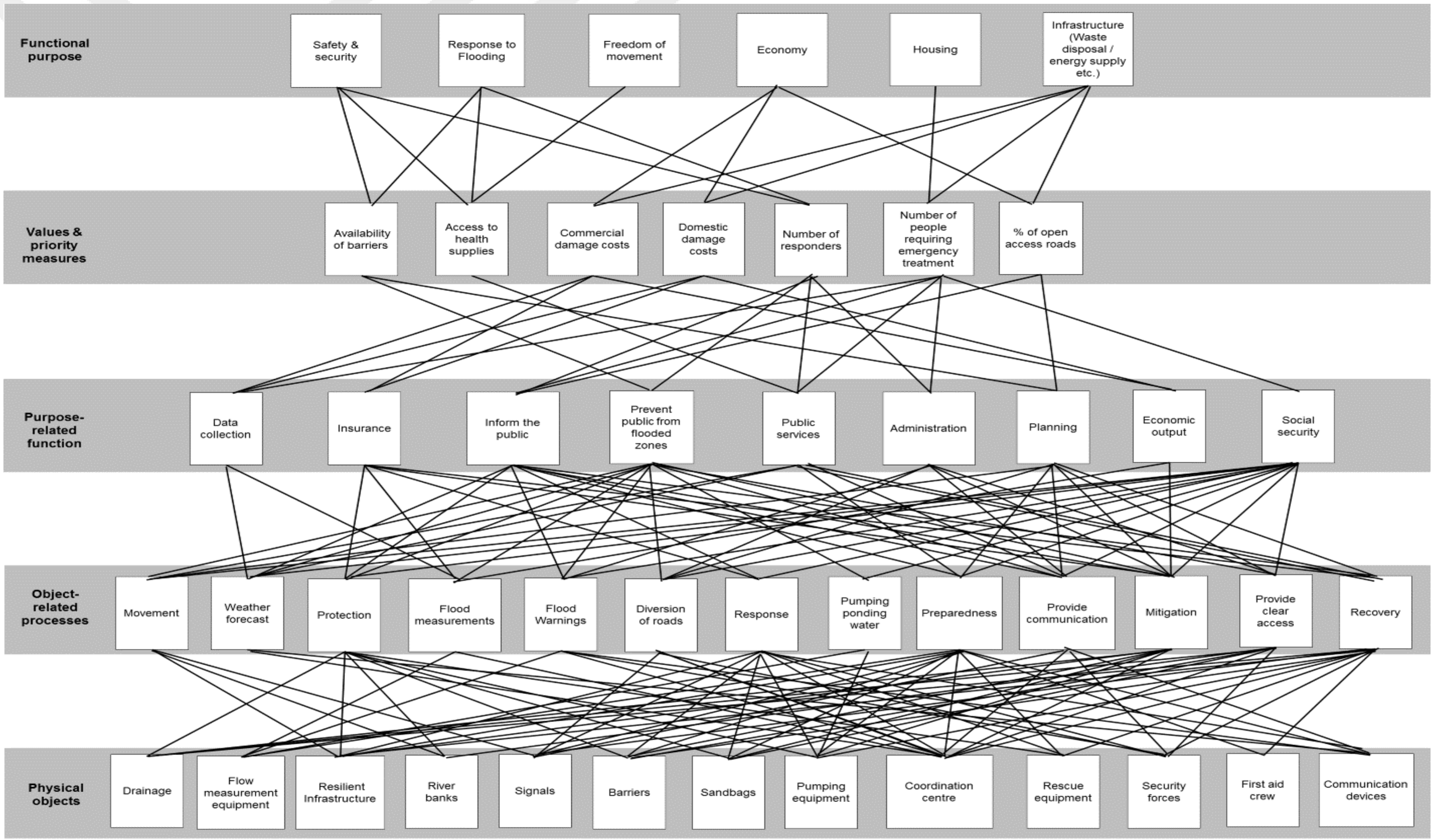


Figure 4-3: Abstraction Hierarchy of Structural and Non-structural flood defences for the town of Turhal

4.1.2. Abstraction Decomposition Space

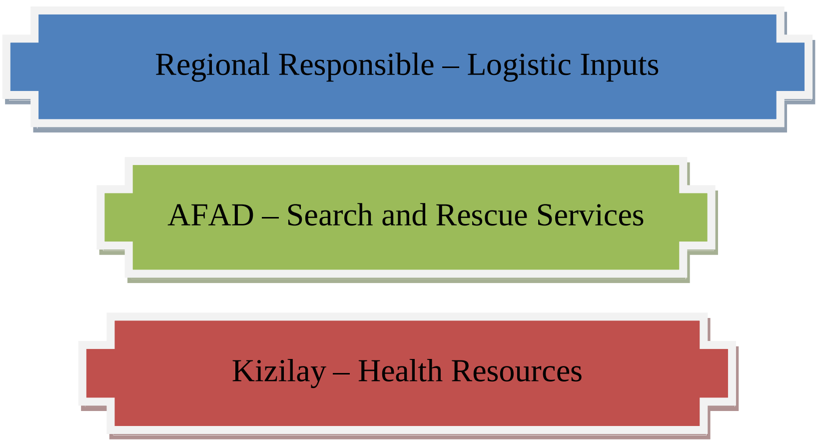
In this paper, the abstraction hierarchies are broken down into three sections; system (as a whole), sub-system and the components as it is displayed in Figure 4-4. The ADS integrates the two abstraction hierarchies populated in the previous section to illustrate the combination of the all the physical objects in the system. By doing so, the easy way of separation of any object or the function is provided to analysts. In addition, ADS enables to evaluate the critical nodes that are considered to be a threat to the overall system functionality.

4.2. Control Task Analysis Results

Contextual Activity Template of the town of Turhal is mapped out and displayed in Figure 4-5. Before beginning to create the template the key crisis management teams and their inputs are indicated. Regional responsible, the local authority of Turhal, comprises both abilities in a limited form. For instance, it has its own health services to treat injured people and search & rescue crews to help people who are affected by the disaster. However, their facilities cannot be comparable with the national resources. By respect to this, additional support teams might be required. AFAD and Kizilay will be mentioned as agencies which will be the responsible for search& rescue and health issues, respectively.

The local authority will be involved in each Flood Planning steps in CAT of Turhal as they accommodate essential inputs for the first response to the flooding. On the other hand, AFAD and Kizilay will be called to action with their inputs and resources according to the CAT in Figure 4-5, where appropriate.

The teams are coloured to draw the attention to Function/Situation table in CAT.



Decomposition / Abstraction	Whole System				Sub-System					Components				
System Purpose / Functional Purpose	Freedom of movement	Economic Activity	Shelter needs to the affected people	Housing										
	Provide safe and secure conditions	Response to Flooding	Cultural Heritage	Infrastructure (Waste disposal / energy supply etc.)										
Domain Values / Value & Priority Measure	Access to Health Supplies	Number of People Requiring Emergency Treatment												
	Number of Responders	% of open access roads	Availability of barriers	Number of Historic Buildings										
	Number of Causalities	Number of people in flood zone	Number of Commercial Buildings	Number of Domestic Buildings										
	Unemployment	Communication	Commercial Damage Costs	Domestic Damage Costs										
Domain Functions / Purpose Related Function					Healthcare	Water Supply								
					Emergency Services	Planning	Economic Output	Social Security	Transportation					
					Data Collection	Insurance Inform the Public	Prevent Public from Flooded Zones	Employment	Public Services					
Technical Functions / Object Related Processes					Movement	Weather Forecast	Protection	Flood Measurements	Flood Warnings	Healthcare Services	Distribute Energy			
					Diversion of Roads	Response	Pumping Ponding Water	Preparedness	Provide Communication	Produce Goods & Services	Provide Leisure Facilities	Provide Utilities	Provide Personal and Emergency Travel	Distribution of Goods
					Mitigation	Provide Clear Access	Recovery	Administration	Energy Supply	Provide Water Services	Provide Social Facilities	Contribute Cultural Heritage	Provide Education Services	Provide Shelter
Physical Resources (Material Configuration) / Physical Objects					Drainage	Flow Measurement Equipment	Resilient Infrastructure			Houses / Dwelling Units	Turhal Sugar Refinery	Turhal Coach Station	Residential Roads	Mosques
					Barriers	Sandbags	Pumping Equipment	Coordination Centre	Rescue Equipment	Milli Egemenlik Public Park	Wells / Water Tanks	Socio-cultural Buildings	A180 High Street	Gultekin Topcam Bridge
					Security Forces	First Aid Crew	Communication Devices	River Banks	Signals	Cumhuriyet Nursery School/ Reformatory	A190 High Street	Petrol Stations	Power Distribution Units	Health Centres

Figure 4-4: Abstraction Decomposition including structural, non-structural defences and physical objects of the town of Turhal

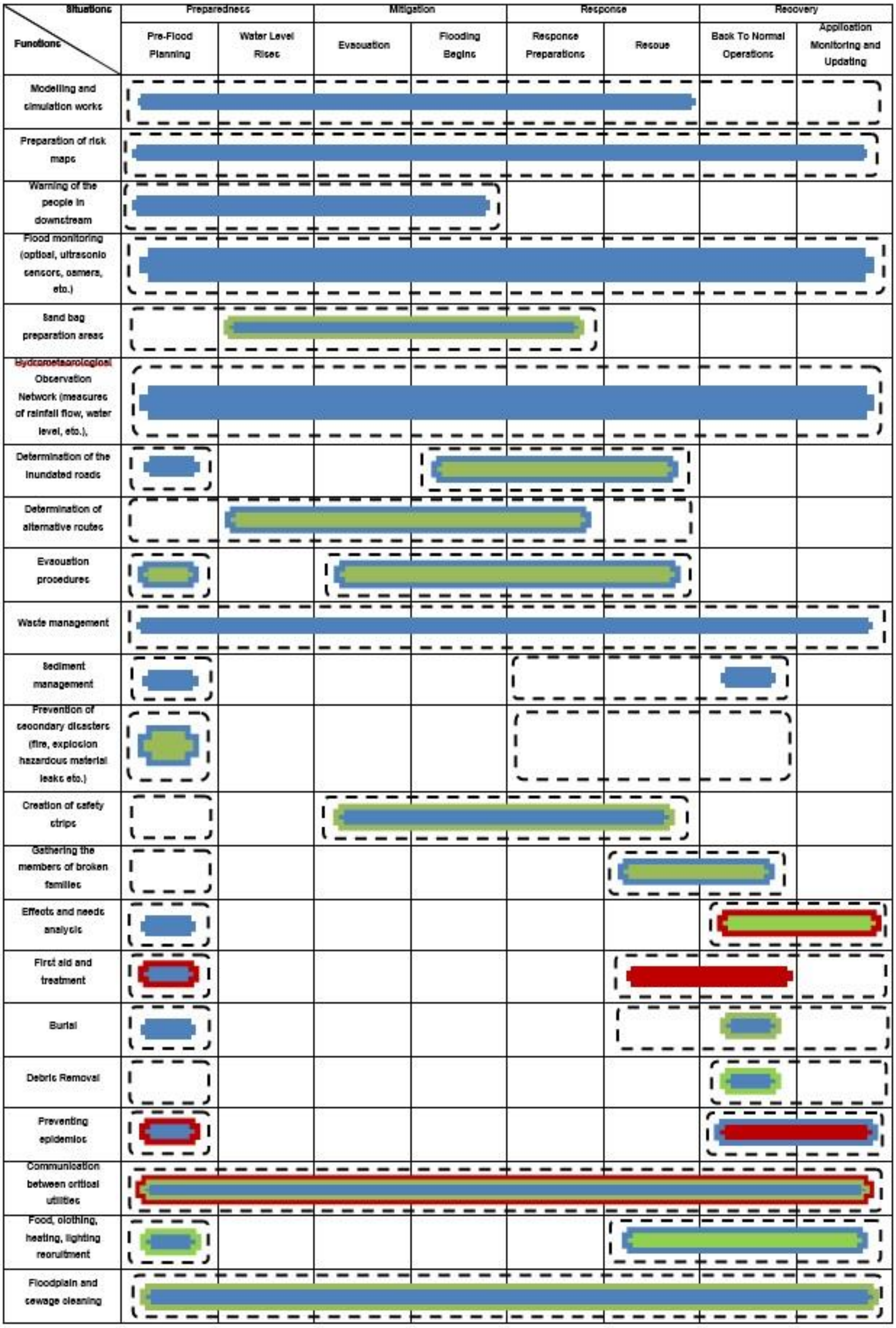


Figure 4-5: Contextual Activity Template (CAT) of Town of Turhal for 1 in 500 year flooding event

The CAT of Turhal demonstrates many capabilities and the constraints of the system that cannot be found in YFRMP. The problem of that management plan that is not mentioning explicitly the steps that must be taken before, during and after the flooding. CAT of Turhal demonstrates those steps with resource allocation.

The dashed boxes in CAT indicate the activity in the specified timeline. The coloured rectangles in the dashed box imply the corresponding crisis team. When the two teams are responsible for the same activity then the rectangle is coloured with both of their colours. However, it must be understood that the inner team of the rectangle has the core responsibility. The dashed boxes with no coloured rectangles reflect the not urgent steps. Therefore, no team is remarked to those slots as any team can be responsible for the activity depending on the availability. If needed, the blanked occasions can be fulfilled with unqualified staff from different teams or can be chosen from the unaffected people from the outside of the flooded zone.

4.3. Strategies Analysis Results

The SA stage is divided into five phases for the town of Turhal. The first phase starts from normal operation to the heavy rainfall beginning. The second phase comprises the stage from heavy rain beginning to the flood alert which is combined with the third phase. The fourth phase goes until the water levels descend. The fifth phase continues till the system back to normal operation. It is again observed from the YFRMP that the strategies during the flooding event were not specified adequately. The shift from the flood planning phase to the post-flood actions is so instant that it is unclear how the city exactly respond to the flooding. The end statement is clearly defined for each strategy in SA stages and displayed in the next pages.

The SA phases enable analysts to implement strategies for different situations. This step of CWA is not well defined in the literature which brings flexible structure. The five stages of flooding for town of Turhal is demonstrated and the actions for each strategy are identified. Some of these actions will take place in SOCA however it is not specified in SOCA that what happened before that action and what is next. SA does not only define those steps but also defines how to do it.

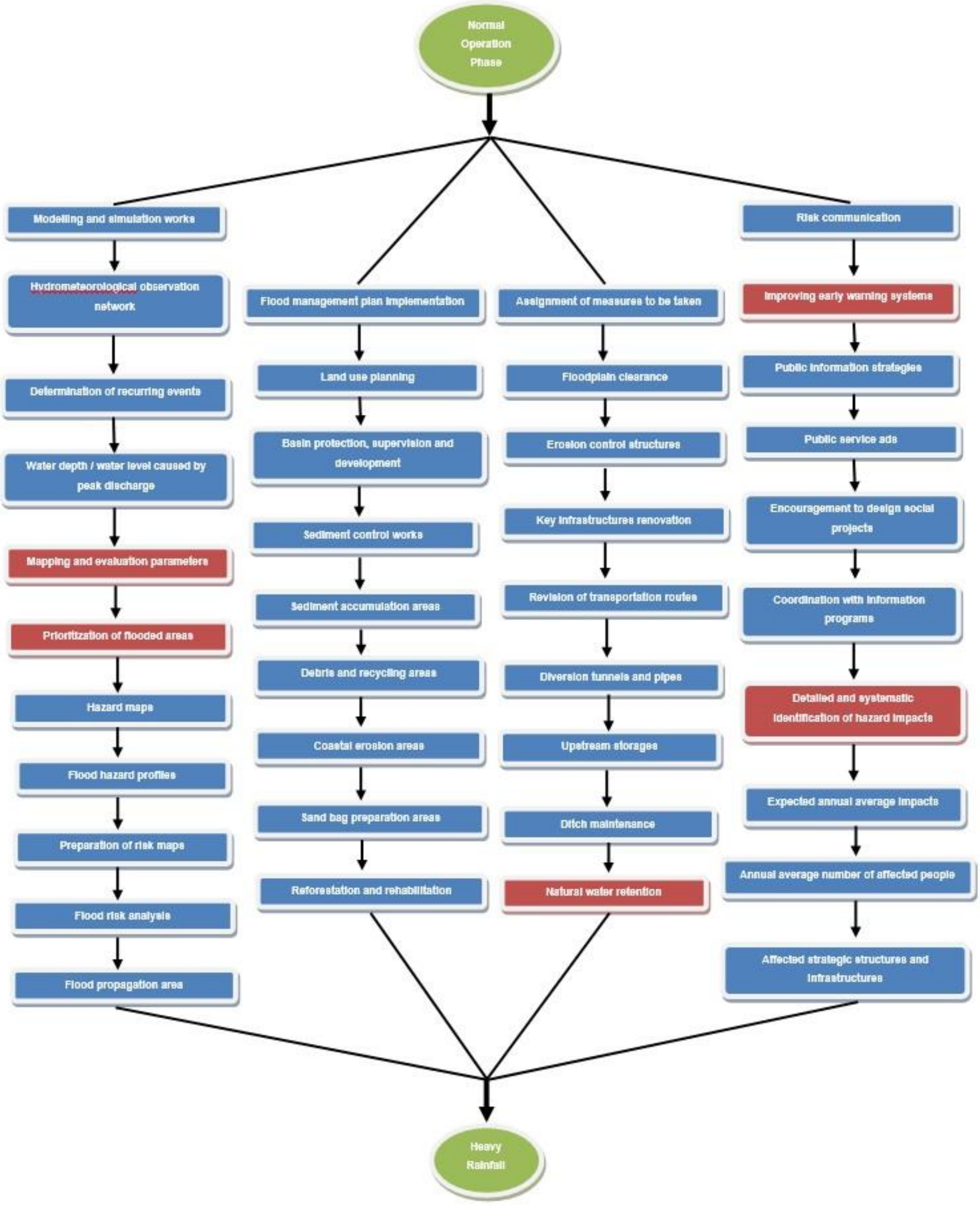


Figure 4-6: Strategies Analysis - 1

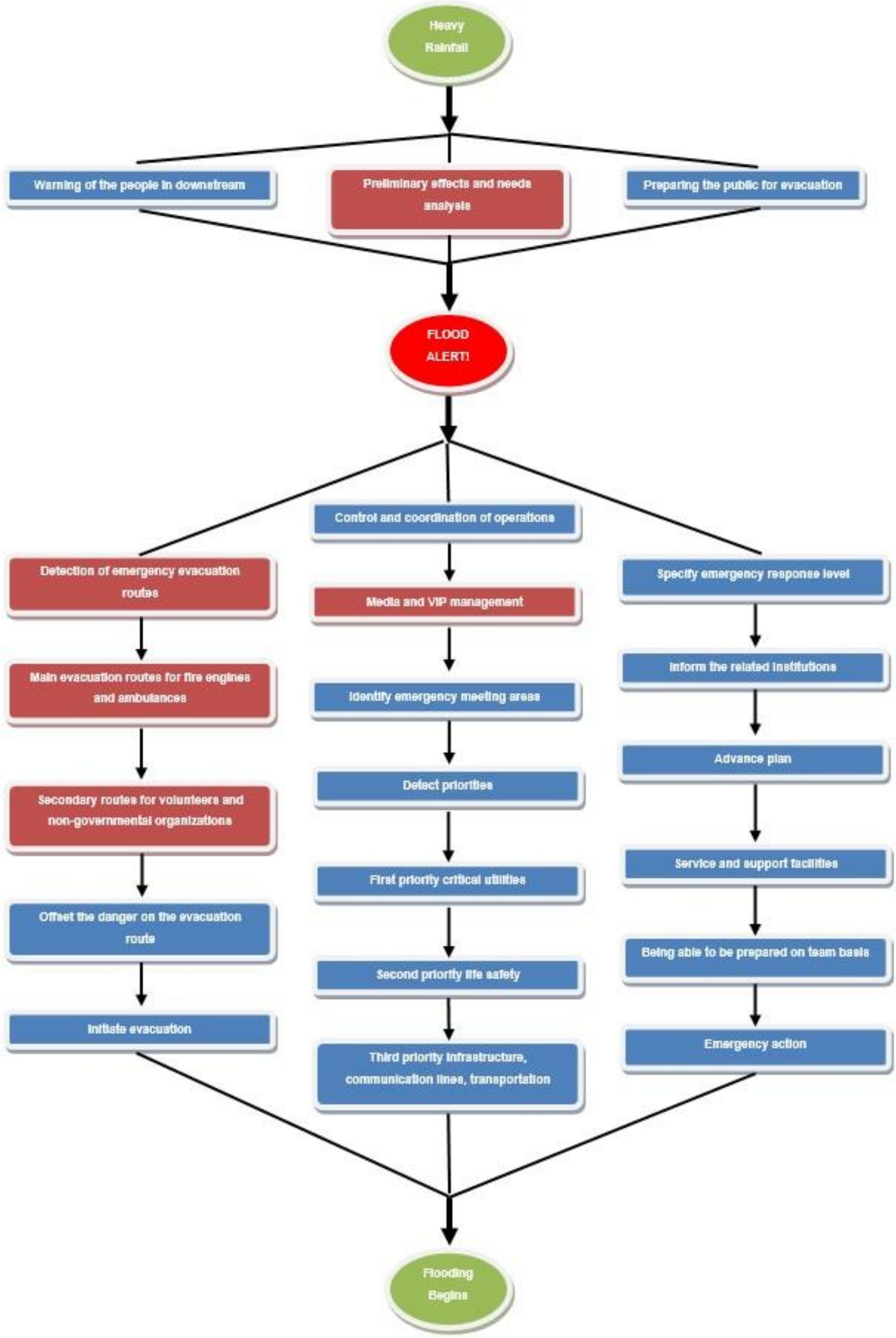


Figure 4-7: Strategies Analysis - 2 & 3

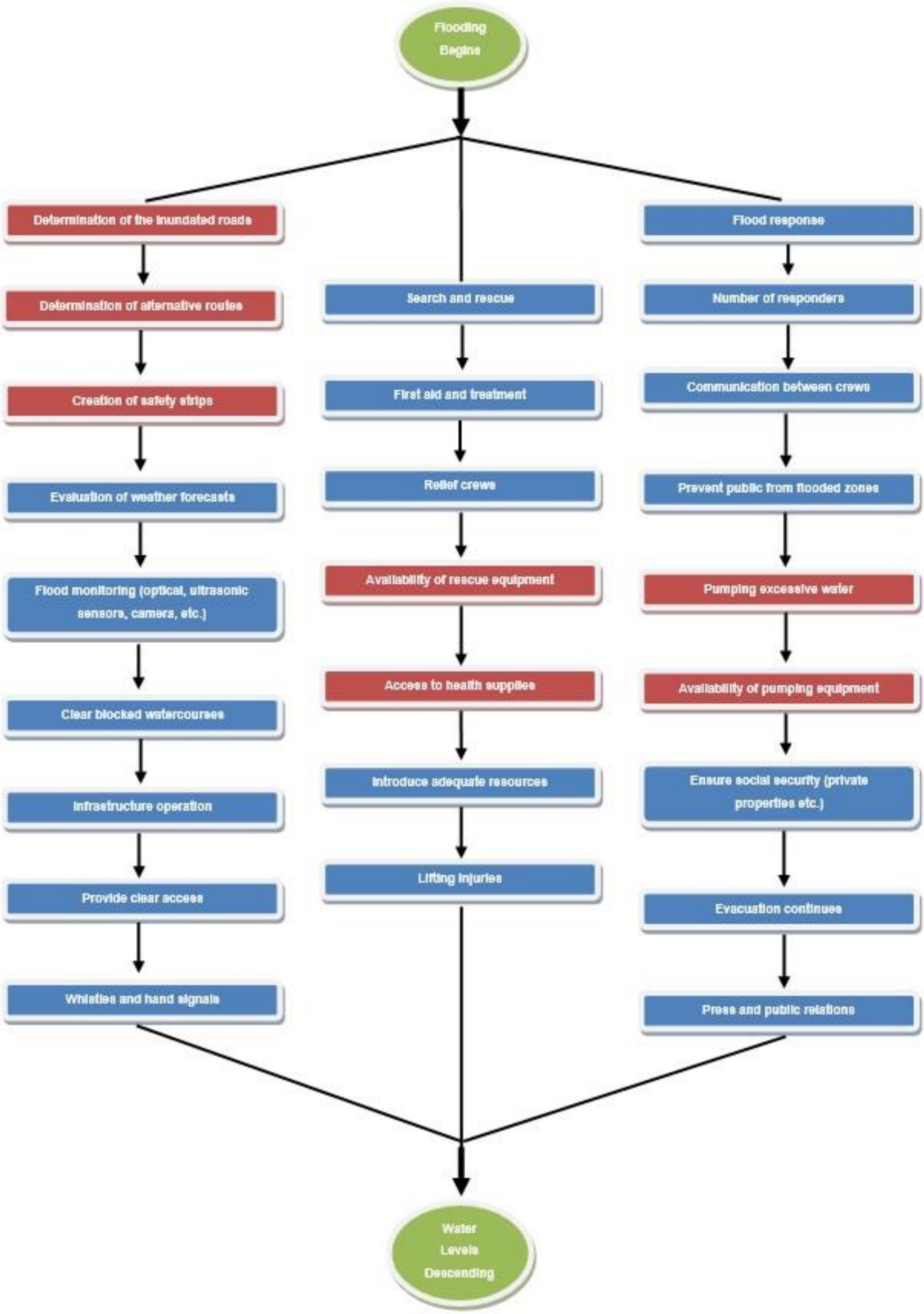


Figure 4-8: Strategies Analysis - 4

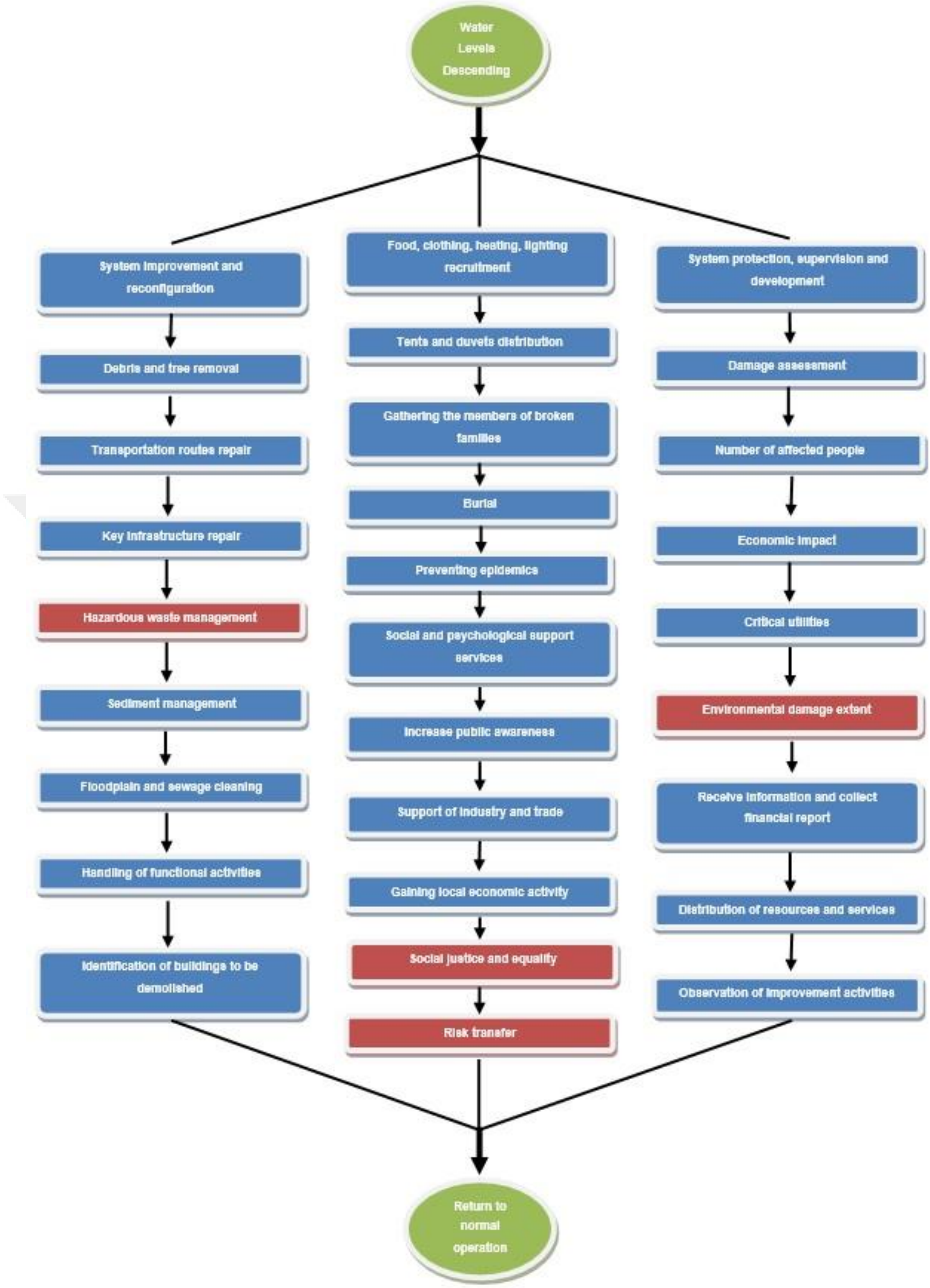


Figure 4-9: Strategies Analysis - 5

The YFRMP did not specify any strategy about the town preparedness for the response stage of the town of Turhal. On the other hand, the actions were mentioned in various subsections in the plan. The SA phase organizes those steps in a sensible form and finds out the missing actions. The required actions are added into the corresponding strategy and can be distinguished by their red colours. This step of CWA is a promising way of evaluating the system resilience against disturbances as it points out the current drawbacks. The organization of SA in this paper highlights the essential requirements of the town of Turhal for each strategy.

Natural water retention mentioned in Strategies Analysis 1 works with other measures to improve flood management in large basins. The benefits of adopting this strategy are (i) reducing the peak flood discharge by gradually releasing flood water over time, (ii) absorbing the water flow by filtration (iii) refilling the aquifers by drainage (iv) providing a natural environment for species.

An important data analysis of the risks associated with urban use mismatches is the link between the transport system that can be used for evacuation and logistics purposes and the communication required for their handling and administration. It should be assessed together with the main transport network in the city and the data of the emergency transportation plan. In respect to this evacuation plan is inserted to SA as it is indicated in Strategies Analysis 3 that emergency evacuation routes must be detected. The routes are obtained after evaluating the roads in two ways. First way includes the assessment of the town as a whole and the routes that connect the town to neighbouring provinces. Second way covers the routes that mainly provide service within the town borders. According to the evacuation plan, the flood propagated area is divided into nine parts and the routes are displayed for each part in Figure 4-10.

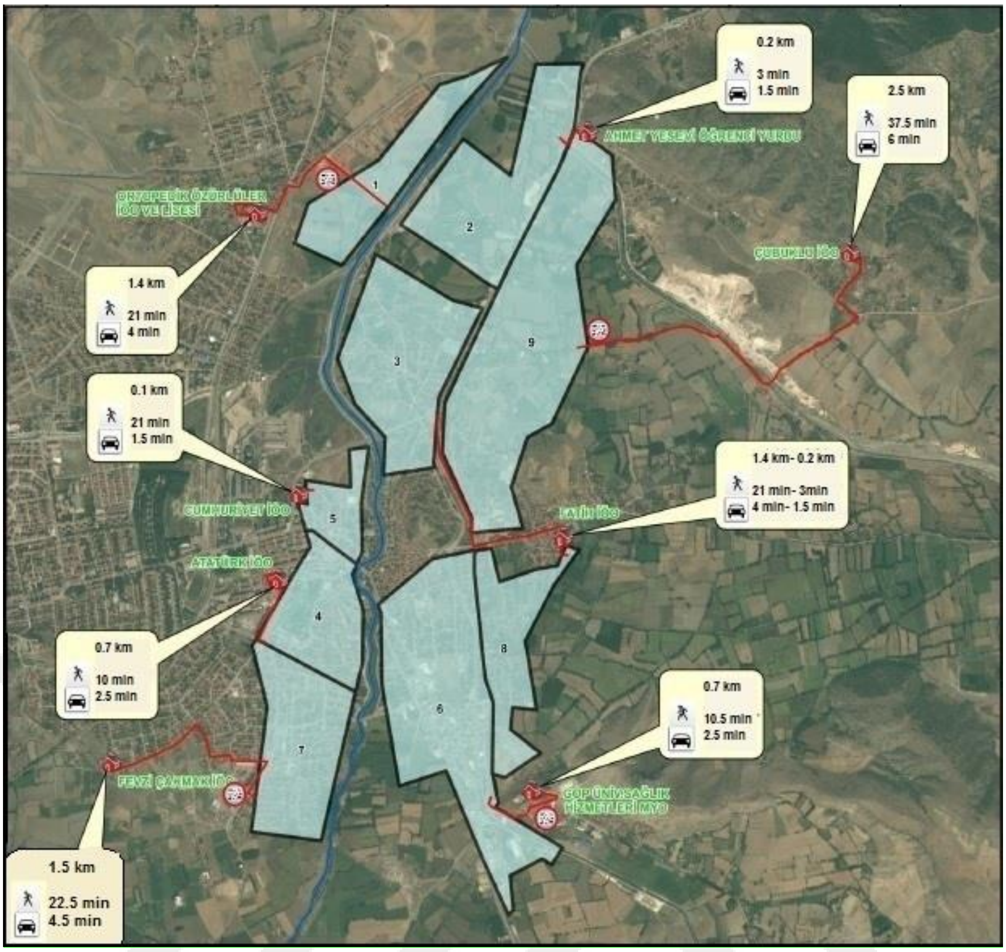


Figure 4-10: The emergency evacuation roads for town of Turhal for 1 in 500 year flooding event

The critical utilities mentioned in Strategies Analysis 3 and 5 are those falling within the borders of 1 in 500 year flooding event. Critical utility provides the necessary products and services as well as the provision of public security and emergency response function. Hospitals, schools, fire stations, dry depots, cold storage depots, indoor sports halls, energy distribution stations, water tanks are prioritised and considered with the necessary infrastructure units in SA stage.

The SA phase is a motion that never ends since the end statement of the Strategies Analysis 5 is the initial state of Strategies Analysis 1. Therefore, the adaptation ability of the system can arise in this eternal phase of CWA.

4.4. Social Organisational & Cooperation Analysis Results

The organisational chart for flood response stage is found in YFRMP specifying the responsible institutions for corresponding response level. However, the communication and cooperation skills cannot be found in existing strategy. Communication aspect will be highlighted in this section as organisational structures were presented in ConTA phase.

RESPONSE LEVEL	EFFECT	SUPPORT CAPACITY BY EVENT TYPE AND SCALE
S1	Local capacity is sufficient	İAADYM
S2	Reinforcements are needed.	İAADYM + Provinces in the Cartchment
S3	Nation-wide support is needed	+ 1st and 2nd Degree Neighbouring Provinces + National capacity
S4	International support is needed.	+ International support

Figure 4-11: The alert levels and related effect/supporter figure of Yesilirmak River Basin *(SYG, 2015)*

IAADYM refers to the regional responsible, i.e. the local authority of Turhal and neighbouring provinces. National capacity stands for the AFAD, Kizilay and non-governmental organizations (NGO). The local administrations intervene in flooding for alert level S1 and S2. AFAD will be involved when the level reaches to S3 as it is displayed in Figure 4-11.

The organisational chart of the head of teams and groups can be seen in Figure 4-12. Additionally, Figure 4-12 will assist to allocate and organise teams specified in Figure 4-11 to enhance communication skills between them. The lieutenant governor is in charge of coordinating teams in local levels S1 and S2. The governor will take over the management when AFAD and other organisations come to assistance. The NGOs will be coordinated under the rule of AFAD's group coordinators.

Teams can be classified into two major groups. One is responsible for planning and operating. The other will execute the instructions and provide logistic facilities. The coordination between teams are crucial as it is mentioned in Strategies Analysis part.

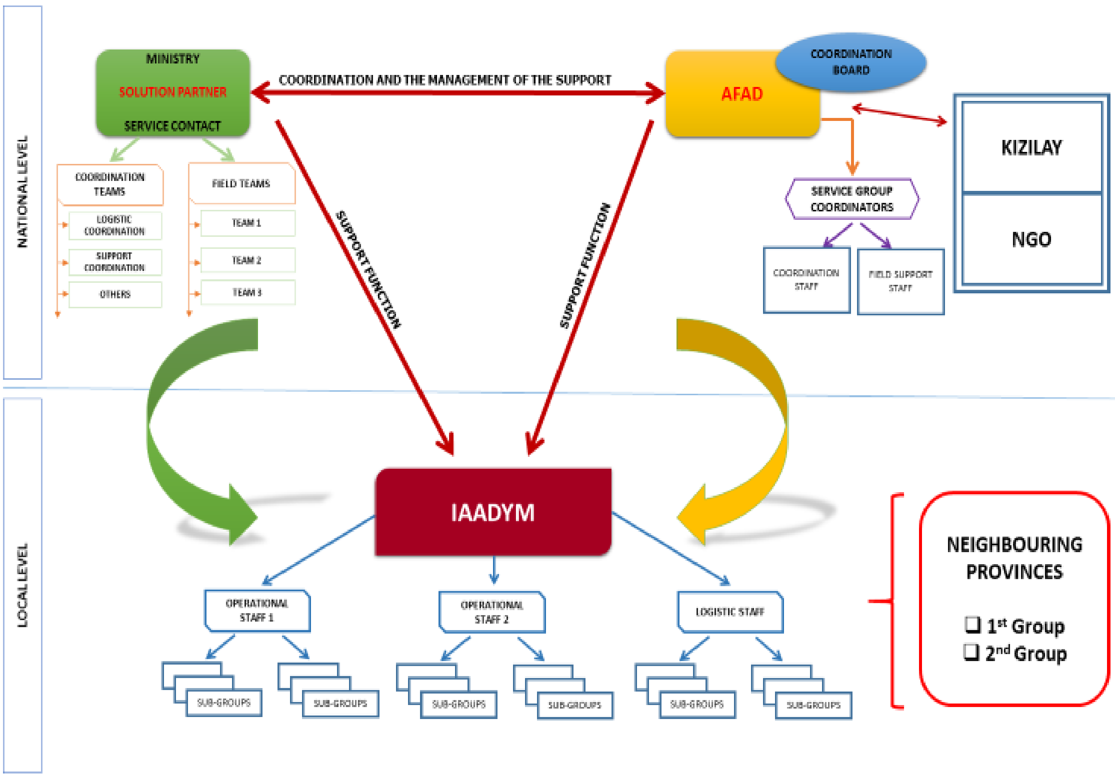


Figure 4-12: The allocation of teams and leaders for local and national level flood response

All steps of CWA must be considered in a holistic way since they complement each other. The last phase of CWA i.e. Workers Competency Analysis (WCA) was not attached into the assessment as the concepts are already included in ConTA and SOCA phases.

Chapter 5

5. Discussions

The Work Domain Analysis (WDA) phase analysed the system capabilities with the variety of relationship and different functions. The insights of the flood management structure were explored in this stage. The what-why-how question sequence demonstrated the interrelations between physical objects and functional purposes. By doing so, the system's challenges and complexity can be observed visually. Two separate abstraction hierarchies were populated to easily examine the separation of any object or function. It can be observed from the AHs that how the disturbance will influence the level above and which node will become non-functional. These two AHs were then populated in one abstraction decomposition space (ADS). It is concluded from the Abstraction Decomposition Space that five of seven overall purposes are common for Abstraction Hierarchy- I and Abstraction Hierarchy- II including; Shelter Needs, Infrastructure, Safety and Security, Economic Activity, Freedom of Movement. Whilst Abstraction Hierarchy- I ensures that purposes are sustained in the system, Abstraction Hierarchy- II is in charge of to secure these objectives. One of the benefits of using CWA method is to consider the system in all functions and abilities. Therefore, flood analysts will be more aware of system constraints while reviewing the preparedness and planning.

Control Task Analysis (ConTA) used Contextual Activity Template (CAT) to consider all situations of the flooding event. It is the first start to flood intervention activities and comprises critical actions for preparedness, mitigation, response and recovery. The resource and input allocation took place in this phase for the town of Turhal. It identified additional constraints for pre, during and post flood periods. It can be deduced from the CAT at first sight that the system highly relies on the local government's activities in the planning phase. Nonetheless, the situations are changing during and after the flood event. More resources and services are required after flooding begins and local inputs become insufficient to meet the town requirements to cope with the disaster.

The least defined and most flexible phase of CWA, Strategies Analysis (SA), offered a good overview of strategies against flood event. SA phase fills the gap left by ConTA.

The prior and following actions of ConTA were specified in SA step. The actions were allocated for five different strategies where the flood alert is clearly mentioned.

Furthermore, the missing points in YFRMP were explored to improve system resilience.

Strategies Analysis 1 in Figure 4-6;

- Improved early warning systems
- Mapping and evaluation parameters
- Prioritization of flood areas
- Natural water retention
- Detailed and systematic identification of hazard maps

Strategies Analysis 2 & 3 in Figure 4-7;

- Preliminary effects and needs analysis
- Media and VIP management
- Detection of emergency evacuation routes
- Main evacuation routes for fire engines and ambulances
- Secondary routes for volunteers and non-governmental organizations

Strategies Analysis 4 in Figure 4-8;

- Crew management
- Determination of inundated roads
- Determination of alternative roads
- Creation of safety strips
- Access to health supplies
- Pumping excessive water
- Availability of pumping equipment

Strategies Analysis 5 in Figure 4-9;

- Hazardous waste management
- Environmental damage extent
- Social justice and equality
- Risk transfer

Some of the identified deficiencies refer to structural and non-structural mitigation measures. Therefore, a balance between these flood defences can be ensured via this phase of CWA.

The communication and cooperation skills of the system were visualised by the favour of Social Organisational & Cooperation Analysis (SOCA). The decision ladder *(see. Appendix-B)* provides a procedure to be followed by responders for the flood site management. The distribution of the responsibilities was not mentioned again since it took place in ConTA stage. The responsible agencies can found “who does what and when” with resource allocation in CAT of Turhal diagram *(see. Figure 4-5).* SOCA explored the connections between agencies and clearly demonstrated the shift from the local level to national level response. It is supported by the allocation of teams *(see. Figure 4-12)* to provide a well-organised diagram to the analysts.

The town of Turhal’s resilience was evaluated by adopting CWA in this paper. The assessment results validated the weaknesses of YFRMP that were found in various sections in this dissertation. CWA was capable to respond almost all shortcomings influencing the system resilience adversely.

Chapter 6

6. Conclusion

In this study, CWA gave a reliable opportunity to assess town of Turhal's resilience and preparedness against natural flooding event. Town of Turhal was well-suited to apply CWA due to its size and analysable nature. The 1 in 500 year flooding threatens the town and existing management plan was not found adequate to respond it.

The remembrance of research questions at the end of Chapter-2 is now crucial to explore the answers.

- How can the issues in the Turhal's current management plan be resolved by Cognitive Work Analysis?

Problem-1: Not considering flood event in all dimensions

ConTA divides flooding in timeline and corresponds each part to preparedness, mitigation, response and recovery sections. CAT of Turhal is not just specifying the temporal distribution of flooding event but also identifies required action with relevant agency. Furthermore, SA shows five different situations and focuses on particular strategies. This phase of CWA distinctly describes the actions that take place before, during and after flooding. SA considers the time flow in a way that contains the entire cycle of the town.

Problem-2: Not providing structural and non-structural defence optimisation

WDA produces the AH- I to integrate both structural and non-structural options. The current structural defences of the town are not found adequate to provide protection against 1 in 500 year flooding. Therefore, new structural measures are added such as pumping equipment, diversion tunnels and pipes, upstream storages. The inserted non-structural defences are improved early warning system, risk transfer, and prioritization of flooded areas. SA identifies these measures in an action sequence to balance and optimise defence options. By doing so, consistent assessment is ensured and improvement opportunities are provided clearly.

Problem-3: Unclear division of responsibility

ConTA defines responsible institutions with their resources and inputs in the system whilst SOCA uses this information to improve communication and collaboration skills of the teams. These two steps are of great importance to highlight the human-environment interaction in the system. The social and technical aspects bring more insights to the assessment by visualization.

- What holistic and multi-faced recommendations can be built to improve Turhal’s resilience in consideration of Cognitive Work Analysis?

First of all, affected utilities and facilities must be identified under favour of Abstraction Hierarchy – I and II. The populated AHs demonstrates that the crucial abilities of the system are highly limited by the impact of 1 in 500 year flooding event. Healthcare, energy supply and transportation facilities should be secured primarily to provide effective service during flooding.

The second emphasis should be put on the evacuation procedures. This is a very complex process which could not be possible to appreciate without the assistance of CWA. It recognises many links connected to evacuation in different assessment steps. WDA ensures clear access while CAT allocates the required resources. The following actions are clarified by SA as preparing the public for evacuation, detection of emergency evacuation routes, the initiation and completion of evacuation.

Last but not least, social point of view should be remembered. This is a very broad term including all humane interactions from affected people to emergency team members. This should be ensured by public information strategies, encouragement of the involvement in social projects and coordination with information programs as it is stated in the first strategy of SA. Additionally, the teams should be trained and organised according to SOCA phase to intervene the flooding event in all steps. The recommendation can be built on interventions comprising the recruitment of lifelines, prevention of epidemics and secondary disasters which can be found in different strategies in SA phase.

The results of the assessment show the required improvements for flood defence options and key development procedures. The CWA brought more societal constraints to the analysis besides defining physical and cultural patterns. CWA did not only evaluate the system resilience but suggested resilient ways to enhance response capacity of the town. This assistance can be considered as the filling the gap between the directive and the implementation.

By applying CWA to town of Turhal it is concluded that the three capabilities of resilience (which is specified by Berkes, (2007)) improve system planning and preparedness; (i) the ability of evaluating hazards holistically i.e. in terms of human-environment coupling relation, (ii) the ability of absorbing the disturbance or adapting to it, and (iii) the ability originated from the forward-looking nature to deal with uncertainty.

This white paper provides comprehensive evaluation of town of Turhal's preparedness and planning against 1 in 500 year flooding. Overall, this application presented clear and coherent information to the decision-makers and flood analysts which should increase the system resilience and reduce the requirements of construction and emergency responses. This is ensured by taking into account of all pre, during and post flooding situations, not neglecting the interconnections between social, physical and technical systems and allocating the roles and resources with communication and coorperation support.

6.1. Future Work

To pursue the studies conducted in this dissertation, some additional investigations should be carried out in further studies. As an initial stage it may be useful to examine the system resilience by removing selected nodes in WDA step.

The CWA is used to evaluate system resilience and suggest resilient mitigation measures to reduce flood risk for town of Turhal. However this conceptual analysis will be effective tool only when it is implemented to the real case. The attention of the relevant institutions must be drawn into CWA to increase staff awareness about socio-technical aspect. This would be particularly useful when public opinion is inserted to the future studies.

A small town of Turkey is evaluated in this assessment. This type of studies must be conducted to assess resilience of all towns in the country to validate the effectiveness of CWA. Further contributions to the assessment can be ensured by applying CWA to the bigger cities.

It can be also recommended that the use of CWA for urban studies should be augmented by the key authors. Consideration should be given to strengthen the connection between theoretical and practical dimensions. Future works may consider the application and comparison of different methods to achieve more effective management plans.

References

ACC/ISGWR, 1992. *The Dublin statement and the report of the conference,* Geneva: WMO.

Adikari, Y. & Yoshitani, J., 2009. *Global Trends in Water-Related Disasters: an insight for policymakers,* Paris: United Nations Educational.

Ahlstrom, U., 2005. Work domain analysis for air traffic controller weather displays. *Journal of Safety Research,* Volume 36, pp. 159-169.

Balica, S., Douben, N. & Wright, N., 2009. Flood vulnerability indices at varying spatial scales.. *Water Science and Technology Journal,* pp. 2751-2580.

Beevers, L., Walker, G. & Strathie, L., 2016. A Systems Approach to Flood Vulnerability. *Civil Engineering and Environmental Systems,* 33(3), pp. 199-213.

Berkes, F., 2007. Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards,* Volume 52, pp. 283-295.

Birkholz, S., Muro, M., Jeffrey, P. & Smith, H., 2014. Rethinking the relationship between flood risk perception and flood management. *Science of the Total Environment,* 478(1), pp. 12-20.

Bisantz, A., 2003. Integrating cognitive analyses in a large-scale system design process. *International Journal of Human-Computer Studies,* Volume 58, pp. 177-206.

Buijs, F., Simm, J., Wallis, M. & Sayers, P., 2007. *Performance and Reliability of Flood and Coastal Defences,* London: DEFRA.

Carvalho, P. V. R. d., 2011. The use of Functional Resonance Analysis Method (FRAM) in a mid-air collision to understand some characteristics of the air traffic management system resilience. *Reliability Engineering and System Safety*, pp. 1482-1498.

Chin, M., Sanderson, P. & Watson, M., 1999. *Cognitive work analysis of the command and control work domain, In Proceedings of the 1999 Command and Control Research and Technology Symposium.* Newport, RI, United States Naval War College.

Corriea, F. N., Fordham, M., Saraiva, M. D. & Bernardo, M., 1998. Flood Hazard Assessment and Management: Interface with the Public. *Water Resources Management*, pp. 209-227.

Cutter, S. et al., 2008. A place-based model for understanding commuity resilience to natural disasters. *Global Environmental Change*, p. 598–606.

De Bruijn, K., 2005. *Resilience and flood risk Management. A systems approach applied to lowland rivers,* Delft: Delft University Press.

De Bruijn, K., Green, C., Johnson, C. & McFadden, L., 2007. Evolving Concepts in Flood Risk Management: Searching for a Common Language. *Flood Risk Management in Europe*, pp. 61-75.

De Brujin, K., 2004. Resilience and flood risk management. *Water Policy*, pp. 53-66.

EU, 2007. *A new EU Floods Directive 2007/60/EC.* [Online] Available at: http://ec.europa.eu/environment/water/flood risk/index.htm [Accessed 20 June 2017].

Fidel, R., Pejtersen, A., Cleal, B. & Bruce, H., 2004. A multi-dimensional approach to the study of human information interaction: a case study of collaborative information retrieval. *Journal of the American Society for Information Science and Technology,* 55(11), pp. 939-953.

Gavan, L., 2013. *Cognitive Systems Design.* [Online] Available at: http://www.cognitivesystemsdesign.net/Tutorials/CWA%20Tutorial.pdf [Accessed 20 June 2017].

GWP, 2000. *Integrated water resources management Global Water Partnership Technical Advisory Committee* , Stockholm: GWP.

Hajdukiewicz, J., 1998. *Development of a structured approach for patient monitoring in the operating room, Master Thesis.* [Online] Available at: https://tspace.library.utoronto.ca/bitstream/1807/12189/1/MQ34145.pdf [Accessed 03 July 2017].

Hall, J., Meadowcroft, I., Sayers, P. & Bramley, M., 2003. Integrated Flood Risk Management in England and Wales. *Natural Hazards Review,* 4(3), pp. 126-136.

Helm, P., 1996. Integrated risk management for natural and technological disasters. *Tephra*, pp. 4-13.

Holling, C., 1973. Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, pp. 1-24.

Holling, C., 2000. *Theories for sustainable futures, Conservation Ecology.* [Online] Available at: https://www.ecologyandsociety.org/vol4/iss2/art7/ [Accessed 18 June 2017].

Hooijer, A., Klijn, F., Kwadijk, J. & Pedroli, B., 2002. *Towards Sustainable Flood Risk Management in the Rhine and Meuse River Basins,* s.l.: NCR.

ICE, 2001. *Learning to live with rivers. Final report of the ICE Presidential Commission to review,* London: Institutioin of Civil Engineers.

IPCC, 2012. *Managing The Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,* Cambridge, UK: Cambridge University Press.

Jamieson, G., Ho, W. & Reising, V., 2003. *Ecological interface design in practice: A design for petrochemical processing operations.* London, Lawrance Elbaum Associates.

Jamieson, G. & Vicente, K., 2001. Ecological interface design for petrochemical applications: Supporting operator adaptation, continuous learning and distributed, collaborative work.. *Computers and Chemical Engineering,* Volume 25, pp. 1055-1074.

Jenkins, D. et al., 2008a. Using cognitive work analysis to explore activity allocation within military domains. *Ergonomics*, pp. 798-815.

Jenkins, D. et al., 2010. Using the decision-ladder to add a formative element to naturalistic decision-making research. *International Journal of Human–Computer Interaction*, 26(2-3), pp. 132-146.

Jenkins, D. et al., 2008b. Applying cognitive work analysis to the design of rapidly reconfigurable interfaces in complex networks. *Theoretical Issues in Ergonomics Science*, pp. 273-295.

Kappes, M. S., Papathoma-Köhle, M. & Keiler, M., 2012. Assessing physical vulnerability for multi-hazards using an indicator based methodology. *Applied Geography*, pp. 577-590.

Katapol, P., 2006. We don't do that here: Using cognitive work analysis to learn about organizational culture. *Bulletin of the American Society for Information Science and Technology*, 33(11), pp. 9-11.

Leveson, N., 2004. A new accident model for engineering safer systems. *Safety Science*, pp. 237-270.

Li, K., 2006. *A critical issue of flood management in China: flash flood, landslide & mudflow disasters, weakness in defense, & countermeasures.* Omaha, World Environmental and Water Resources Congress.

Mazaeva, N. & Bisantz, A., 2007. On the representation of automation using a work domain a analysis. *Theoretical Issues in Ergonomics Science,* 8(6), pp. 509-530.

Memesevic, R., Sanderson, P., Choudhury, S. & Wong, W., 2005. *Work domain analysis and ecological interface design for hydropower system monitoring and control. In: Proceedings of the IEEE Conference on Systems, Man, and Cybernetics.* Hawaii, IEEE.

Merz, B., Hall, J., Disse, M. & Schumann, A., 2010. Fluvial flood risk management in a changing world. *Natural Hazards and Earth System Sciences*, pp. 509-527.

Mileti, D., 1999. *Disasters by Design.* Washington DC: Joseph Henry Press.

Miller, K., 1992. A Framework for Integrated Risk Management in International Business. *Journal of International Business Studies*, pp. 311-331.

Naikar, N., 2011. *Cognitive Work Analysis: Foundations, Extensions, and Challenges,* Melbourne: Air Operations Division.

Naikar, N., Hopcroft, R. & Moylan, A., 2005. *Work domain analysis: theoretical concepts and methodology.* DSTO-TR-1165 ed. Melborne: DSTO.

Naikar, N., Lintern, G. & Sanderson, P., 2002. Cognitive work analysis for air defense applications in Australia. *Research Gate*, pp. 169-200.

Naikar, N., Moylan, A. & Pearce, B., 2006. Analysing activity in complex systems with cognitivework analysis: Concepts, guidelines, and case study for control task analysis.. *Theoretical Issues in Ergonomics Science*, pp. 371-394.

Naikar, N., Pearce, B., Drumm, D. & Sanderson, P., 2003. Technique for designing teams for first-of-a-kind complex systems with cognitive work analysis: Case study. *Human Factors*, 45(2), pp. 202-217.

Naikar, N. & Sanderson, P., 1999. Work domain analysis for training-system definition. *International Journal of Aviation Psychology,* Volume 9, pp. 271-290.

Naikar, N. & Sanderson, P., 2001. Evaluating design proposals for complex systems with work domain analysis. *Human Factors,* Volume 43, pp. 529-542.

Naikar, N. & Saunders, A., 2003. Crossing the boundaries of safe operation: A technical training approach to error management. *Cognition Technology and Work,* Volume 5, pp. 171-180.

OFDA & CRED, 2015. *International Disaster Database.* [Online] Available at: http://www.emdat.be/
[Accessed 07 June 2017].

Olorunfemi, F., 2011. *Managing flood disasters under a changing climate: Lessons from Nigeria and South Africa.* [Online] Available at: http://www.mistraurbanfutures.org/en/managing-flood-disasters-under-changing-climate-lessons-nigeria-and-south-africa
[Accessed 10 June 2017].

Olsson, G. & Lee, P., 1994. Effective interfaces for process operators. *The Journal of Process Control,* Volume 4, pp. 99-107.

Pejtersen, A. et al., 2001. *Empirical work analysis of collaborative film indexing in Proceedings of the Fourth International Conference on Conceptions of Library and Information Science.* Greenwood Village, Eds. Libraries Unlimited.

Pejtersen, A. & Rasmussen, J., 1997. Systems design and evaluation. In: *Handbook of human factors and ergonomics.* New York: Wiley, p. 1514–1542.

Pérez-España, H. & Arreguín-Sánchez, F., 1999. Complexity related to behaviour of stability in modelled coastal zone ecosystems. *Aquatic Ecosystem Health Management*, pp. 129-135.

Pielke Jr., R., 2000. Flood impacts on society. Damaging floods as a framework for assessment, in: Floods. *Routledge Hazards and Disasters Series*, pp. 133-155.

Plate, E., 2002. Flood risk and flood management. *Journal of Hydrology,* Volume 267, pp. 2-11.

Plate, E., 2009. Classification of hydrological models for flood management. *Hydrology and Earth System Sciences,* 13(10), pp. 1939-1951.

Rasmussen, J., 1997. Risk management in a dynamic society: a modelling problem. *Safety Science,* pp. 183-213.

Rasmussen, J., Pejtersen, A. & Goodstein, L., 1994. *Cognitive systems engineering.* New York: John Wiler and Sons.

Sahin, D., 2013. *Flood Risk Management in Turkey,* Ankara: AFAD.

Saidu, I. & Lal, M. D., 2015. Flood risk inevitability and flood risk management in urban areas: A review. *Journal of Geography and Regional Planning,* pp. 205-209.

Salmon, P., 2007. Work domain analysis and road transport: Implications for vehicle design. *International Journal of Vehicle Design,* 45(3), pp. 426-448.

Salmon, P., Jenkins, D., Stanton, N. & Walker, G., 2010. Hierarchical task analysis vs. cognitive work analysis: comparison of theory, methodology and contribution to system design. *Theoretical Issues in Ergonomics Science,* pp. 504-531.

Sanderson, P., 2000. *Cognitive work analysis across the system life-cycle: Achievements, challenges, and prospects.* Manly, Australia, Australian Aviation Psychology Symposium.

Sanderson, P. et al., 2004. Visual and auditory attention in patient monitoring: a formative analysis. *Cognition, Technology & Work,* 6(3), pp. 172-185.

Sanderson, P., Naikar, N., Lintern, G. & Goss, S., 1999. *Use of cognitive work analysis across the system life cycle: Requirements to decommissioning In Proceedings of the Human Factors andErgonomics Society 43rd Annual Meeting.* Santa Monica, CA, Human Factors and Ergonomics Society.

Sayers, P., Hall, J. & Meadowcroft, I., 2002. Towards riskbased flood hazard management in the UK. *Civil Engineering,* 150(1), pp. 36-42.

Schraagen, J., Chipman, S. & Shalin, V., 2000. *Cognitive task analysis.* Mahwah, NJ: Lawrance Erlbaum Associates.

Shepherd, A., 2001. *Hierarchical task analysis.* London: Taylor & Francis.

Simonovic, 1999. Decision support system for flood management of floods in the Red River Basin. *Canadian Water Resources,* 24(3), pp. 203-223.

Simonovic, S., 2011. *Systems Approach to Management of Disasters: Methods and Applications.* Hoboken, NJ: John Wiley & Sons Inc..

Simonovic, S., 2012. *Floods in a Changing Climate: Risk Management.* Cambridge: Cambridge University Press.

Smith, K., 2013. *Environmental Hazards: Assessing Risk and Reducing Disaster.* 6th ed. New York: Rouledge.

Smith, K. & Ward, R., 1998. *Floods: Physical Processes and Human Impacts.* New York: John Wiley & Sons.

SYG, 2015. *Yesilirmak Flood Risk Management Plan,* Ankara: Su Yonetimi Genel Mudurlugu.

TUIK, 2013. *Turhal Economy with Selected Legends,* Ankara: Turkish Statistical Institute.

TUIK, 2016. *Turkish Statistical Institute.* [Online] Available at: https://biruni.tuik.gov.tr/medas/ [Accessed 18 June 2017].

Turner, B., Kasperson, R. & Matson, P., 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States,* Volume 100, pp. 8074-8079.

UN/ISDR, 2002. *Living with risk: a global review of disaster reduction initiatives (preliminary version).,* Geneva: United Nations.

UN/ISDR, 2004. *Living with risk: A global review of disaster reduction initiatives, United Nations, International Strategy for Disaster Reduction,* Genf: United Nations .

UN/ISDR, 2009. *UNISDR terminology on Disaster Risk Reduction. International Strategy for Disaster Reduction,* Geneva: United Nations.

UN, 1992. *Internationally agreed glossary of basic terms related to disaster management (DNA/93/36)*, Geneva: United Nations.

UNDRO, 1991. *Mitigating natural disasters phenomena effects and options, A Manual for Policy Makers and Planners*, New York: United Nations.

Vicente, K., 1995. Supporting operator problem solving through ecological interface design. *IEEE Transactions on Systems, Man, & Cybernetics,* Volume 25, pp. 529-545.

Vicente, K., 1999. *Cognitive work analysis: Toward safe, productive, and healthy computer-based work.* Mahwah, NJ: Lawrence Erlbaum Associates.

Vicente, K., 2002. Ecological interface design: Progress and challenges. *Human Factors*, 44(1), pp. 62-78.

Vis, M., Klijn, F., De Brujin, K. & Van Buuren, M., 2003. Resilience strategies for flood risk management in the Netherlands. *International Journal of River Basin Management*, pp. 33-40.

Walker, B., Holling, C., Carpenter, S. & Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society,* 9(2), p. 5.

Waller, M., 2001. Resilience in ecosystemic contex: evolution of the concept. *Am. J. Orthopsychiatry,* pp. 1-8.

Ward, R., 1978. *A Geographical Perspective.* London: London Macmillan Press Ltd..

Watson, M. & Sanderson, P., 2007. Designing for attention with sound: Challenges and extensions to ecological interface design. *Human Factors*, 49(2), pp. 331-346.

Wisner, B., Blaikie, P., Cannon, T. & Davies, I., 2004. *At Risk: Natural hazards: people's Vulnerability and Disasters.* london: Routledge.

WMO, 2009. *Integrated Flood Management,* Geneva: WMO.

Appendices

Appendix A-1: The list view of measures for the cities and towns in Yesilirmak Catchment

MEASURES													
No	The Area (Province/Town)	The River	Type of Measure	Timing	Measure	Explanation of Measure	Responsible Institute	Relevant Authority	Legal Foundation	Priority Level	Construction Period	Previous Measures	Target
16	TOKAT Turhal	Yesilirmak	Structural	Pre-flood	River Training	The existing river banks starting from a 1.5 km upstream of the merge point of Yesilirmak River and Hamidiye Stream and continuing up to a kilometre upstream from the Gultekin Topcam Bridge should be revised to deal with the 1:500 year flooding discharges.	DSI	The Council of Turhal	DSI Law of establishment no: 6200 Council Law no: 5393	High	2016-2021	1.5 km long river dike was constructed between 1953-1981.	1

TARGETS
1 Mitigation
2 Response
3 Recovery
4 Preparedness

Appendix A-2: The map layout for the corresponding measure for Town of Turhal

Appendix B: The decision and process ladder over flooding event