Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam:

A Multi-Perspective Study Using a Multi-Framing Approach

By

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A thesis
submitted to Victoria University of Wellington
in fulfilment of the requirements for the degree of
Doctor of Philosophy

Victoria University of Wellington
2023

Abstract

Egypt depends on the Nile River to secure 98% of the water it needs for different purposes. About 96% of this water originates outside Egyptian territory. Ethiopia alone is the source of 86% of the Nile's water. In 2011, Ethiopia announced the construction of a new dam, called the Grand Ethiopian Renaissance Dam (GERD) at the headwaters of the Nile. The construction of the GERD will have many consequences and risks for Egypt, whose livelihood currently depends on the Nile's water. The perceptions of these risks differ dramatically depending on the adopted perspective in studying them. Studies to date have analysed these risks by using one or two perspectives at a time, leading to limited assessments of this conflict. In addition, these studies did not take into consideration many other aspects and many other impacts that could affect the situation and outcomes. However, in Egypt's critical situation and surrounding circumstances, many perspectives must be adopted to gain a better understanding of the nature of these risks.

The purpose of this research is to study risks to Egypt's water supply in general and the Egyptian agricultural sector in particular, because of the GERD's construction and operation. This study achieves its aims by using different perspectives, frameworks, and tools to understand the nature of the studied risks; identify the root causes; evaluate expected risks; understand how to control, alleviate, and mitigate them; and address the implications for Egypt in general, and for Egypt's agricultural sector in particular. The Egyptian agricultural sector is expected to be one of the most affected sectors since 70% of the Egyptian share of the Nile is consumed by agricultural activities. This research focuses on studying the risks to that sector because of its significant impact on Egypt.

This study utilises different perspectives and multiple lenses of complementary analytical frameworks. These perspectives include the historical, legal, risk, and Theory of Constraints (TOC) perspectives, while the frames include historical, legal, probability-impact matrix (PIM), decision trees, decision tables, and a suite of TOC frames. This research adopts a mixed approach, quantitative and qualitative, using literature as well as primary data obtained through interviews at the international and national levels to reveal and evaluate the real situation.

In the context of this study, the first two frameworks used shed light on the historical and legal nature of the Egyptian-Ethiopian dispute. These two frames provide an evaluation of the past and current situation to build on for the future. Both frames use a literature review approach to explain their perspectives in the form of descriptive analysis.

The other analytical frames use primary data obtained by interviews in a prescriptive analysis. These interviews give voice to different international experts and Egyptian stakeholders. PIM, decision trees, and decision tables frames use primary data from international interviews. PIM frame assesses the expected probabilities and severity of positive and negative risks due to the GERD on Egypt to classify and prioritise these risks. Decision trees and decision tables frames evaluate and compare the Egyptians' decision alternatives based on different scenarios and suggest new decision alternatives.

The TOC frames use five different tools of the TOC Thinking Process tools (TPs) and TOC five focusing steps (5FS). TOC identifies a significant number of root causes of the situation and clarifies their undesired effects by analysing its current state, which indicates the under-achievement of the sector's goals. It also addresses the implications for Egypt

because of these undesirable effects and offers different solutions that when implemented could help to overcome such problems.

This study contributes theoretically to the literature in several ways. Firstly, using the multi-framing approach to study Egypt's situation due to the GERD provides a new theoretical approach, which acknowledges and addresses the complexity of such situations. Secondly, it demonstrates how one might conduct a study of the expected risks taking different points of view through an integrated risk analysis combining different risk analysis methods to provide a fuller and more comprehensive analysis. Lastly, the researcher uses the TOC Current Reality Tree (CRT) in a non-standard way, adding a new TOC TP tool, the "Conditional Reality Tree" (Cond. RT). This tool provides the opportunity to study scenarios that are expected to become reality in the near future based on a conditional situation, rather than capturing current reality.

This study also makes methodological contributions. One of the main methodological contributions is made by contributing to the multi-framing body of knowledge through the multi-framing approach of this study. This research is also an addition to the literature of the integration of studying the expected risks regarding the Egyptian situation from different points of view. Another methodological contribution is the unique combination of frames included, in addition to the sequential use of frameworks used. This innovative methodology itself is a key contribution of the thesis. No similar study has been conducted elsewhere by using this integrated approach. Moreover, the analytical frames used provide a methodological framework for other similar disputes over shared watercourses and other natural resources. The proposed framework is considered one of the first frameworks that could be used in settling disputes over shared watercourses elsewhere.

Moreover, the study's findings make valuable contributions to different stakeholders and decision makers who can benefit significantly from the study through its recommendations and address cause-effect relationships limiting desirable outcomes from actions taken. The researcher found that the complexity of relationships linking root causes and their undesirable effects (UDEs) of this situation was totally underestimated when compared to those highlighted by the literature. These findings were gained by applying TOC. This is the first study of its kind worldwide to address the Egyptian-Ethiopian dispute using the TOC – both the TPs and 5FS - as well as being the first time that TOC has been applied to an international water dispute.

In terms of its contribution to practice, the study suggests applicable insights from these different perspectives for Egyptian decision makers and stakeholders. An integrated framework approach is developed that makes very useful suggestions. It also provides decision makers and stakeholders with a platform for understanding the sector in order to support their decision-making process to ultimately improve its outcomes. In particular, the study makes several significant recommendations related to water practices, agricultural practices, national/governmental issues, new water resource alternatives other than the Nile, and Egypt's international and foreign affairs.

Acknowledgement

"It is not about the destination, but the journey". You cannot achieve anything entirely by yourself during this journey. You have to have people that you can rely on. I am lucky to have a great support system in my life.

I would like to express my perpetual gratitude and thanks to my family and friends who have had to put up with many challenges over the course of this study. Special thanks to my brother Amr, my backbone, many things in my life would not have been possible without your help and support.

I wish to thank my supervisors to whom I owe my deepest gratitude, Emeritus Professor Vicky Mabin and Dr Bronwyn Howell. To Vicky, "thank you" is not enough for me to express how grateful I am for your support over the years. You are my mentor. It would not have been possible without your understanding and support. You have changed the way I look at the world. To Bronwyn, thank you for all the years of guidance and advice you have bestowed upon me. Your words of encouragement, insights and advice kept me sane while chasing this dream. It was a privilege to work under the supervision of both of you. Please accept my sincere appreciation. What I owe you both is immeasurable.

I also wish to thank all the staff and colleagues from the School of Management, Victoria University of Wellington, who have contributed to the study directly and indirectly. Big thanks to the International Development Scholarships team, Clemmie Newton, Ryan Stuart, and Vivian Wei for their support and continued help. To the research participants who voluntarily shared their knowledge and helped me see the bigger picture, thank you. Financial support from New Zealand's Ministry of Foreign Affairs and Trade (MFAT) Manaaki Scholarship is gratefully acknowledged.

Finally, I would like to dedicate this work to the martyrs and heroes of the Egyptian revolution in January 2011, some of whom are still in jail, some still fighting for their freedom all over the world; your steadfastness and determination make us proud. I salute you. I will always remember you. I promise that we will always feel injustice committed against anyone, anywhere and we will stand up against it. It has been said, "We are waiting for a glance or a word, some acknowledgement that we are here". This dedication is to acknowledge that we once were here.

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5FS	5 Focusing Steps
ABNMS	Australasian Bayesian Network Modelling Society
AHD	Aswan High Dam
AU	African Union
BC	Before Christ
bcm	billion cubic metres
BHPP	Baglihar Hydroelectric Power Project
BRs	Berlin Rules on water resources (2004)
CARU	Administrative Commission of the River Uruguay
CESCR	UN Committee on Economic, Social and Cultural Rights
CFA	Cooperative Framework Agreement 'Entebbe Treaty'
CIDA	Canadian International Development Agency
CLRs	Categories of Legitimate Reservations
Cond. RT	Conditional Reality Tree
CR	Critical realism
CRB	Current Reality Branch
CRT	Current Reality Tree
CSFs	critical success factor(s)
DBM	Drum-Buffer-Rope method
DE(s)	desirable effect(s)
DMUCR	decision making under conditions of risks
DMUCU	decision making under conditions of uncertainty
DoP	The Agreement on Declaration of Principles on the GERD
EC	Evaporating Cloud
EGP	Egyptian Pound
Egy	International interviews - Egyptian participants
ENSAP	Eastern Nile Subsidiary Actions Program
EU	European Union
Eur	International interviews - European participants
EV	Expected Value criterion
FAO	Food and Agriculture Organisation of the United Nations
FRT	Future Reality Tree
GDP	Gross Domestic Product
GERD	Grand Ethiopian Renaissance Dam
GT	Goal Tree
HEC	Human Ethics Committee
HRs	Helsinki Rules (1966)
ICJ	International Court of Justice
IL	National interviews - participants in the industry category
ILA	International Law Association
ILC	International Law Commission
Inj(s)	Injection(s)
IO(s)	Intermediate Objective(s)
IOM	Intermediate Objectives Map
IPOE	International Panel of Experts
IRAC	Issue, Rule, Analysis, and Conclusion legal framework
IWT	Indus Waters Treaty
JCP	Jonglei Canal Project

km	Kilometre
LL	National interviews - participants in the local category
m	Metre
maf	Million acre feet
mcm	million cubic meters
METEC	Metals and Engineering Corporation
NBC	Nile Basin Commission
NBI	Nile Basin Initiative
NCs	Necessary Condition(s)
NE	Neutral expert
NELSAP	Nile Equatorial Lakes Subsidiary Actions Program
NL	National interviews - participants in governmental level/national category
NRBAP	Nile River Basin Action Plan
NSAS	Nubian Sandstone Aquifer System
NTC	Nile Tripartite Committee
Obs	Obstacle
Oth	International interviews - participants from other countries
PCIJ	Permanent Court of International Justice
PIM	Probability and Impact matrix
PMI	Project Management Institute
PRT	Prerequisite Tree
RCs	Root causes
SAP	Subsidiary Actions Program
SI	Supplemental Irrigation
SVP	Shared Vision Program
TECCONILE	Technical Committee for the Promotion of the Development and Environmental Protection of the Nile Basin
TNC	Technical National Committee
TOC	Theory of Constraints
TPs	Thinking Processes
UDE(s)	Undesirable effect(s)
UK	United Kingdom
UN	United Nations organization
UNC	UN Convention on the Law of Non-Navigational Uses of International Watercourses (1997)
UNDP	United Nations Development Programme
UNSC	UN Security Council
UpC	International interviews - participants from upstream countries
USA	United States of America
US ($)	United States Dollar
WB	World Bank
WMO	World Meteorological Organisation

Chapter 1
Introduction

"The key to wisdom is this – constant and frequent questioning, for by doubting we are led to question, by questioning we arrive at the truth" (Peter Abelard).

1.1. Introduction

Egypt is one of the world's oldest cradles of civilization. The Nile River is the main reason why civilisation began in Ancient Egypt, due to the resources of the great river (Ibrahim, 2010). In the fourth century Before Christ (BC), the ancient Greek historian Herodotus described Egypt as "the gift of the Nile", because it owed its survival to the Nile.

Egypt is still very highly dependent on the Nile to supply most of its water needs (Abdulrahman, 2019). Moreover, Egypt already suffers from water poverty, with the situation getting worse each year due to rapid population growth (El Bedawy, 2014).

Around 2011, Ethiopia started constructing a new dam on the Blue Nile (Salman, 2016). There are many risks and some opportunities for Egypt expected from this dam construction. However, most of the risks are negative as will be explained later.

It is expected that the construction and operation of this dam will considerably decrease the Nile's water flow to Egypt, especially during the filling time of the dam's reservoir. However, the impacts will extend to other long-term impacts (Abdulrahman, 2019). The damage to the Egyptian agricultural sector is expected to be the greatest since it is the sector that consumes most of the Nile's water (Abdelsalam et al., 2014).

Hence, the Nile's water is a matter of life and death for Egyptians because of its crucial significance to the nation (McKenzie, 2012). The situation is extremely complex and challenging given that many aspects must be considered to gain a better understanding of the nature of these risks and find solution(s). Yet studies to date have analysed the situation by using only one or two perspectives at a time, leading to limited and single-track assessments of this conflict. Consequently, the criticality of Egypt's position has not necessarily been considered in a comprehensive manner.

Therefore, this thesis research set out to study the Egyptian situation, employing multiple perspectives and a multi-framing approach, which will be extremely useful to aid understanding of the situation and support decision makers to find better solutions and improve the overall outcomes for the country's agricultural sector.

This chapter starts with the motivation for this research, its purpose, objectives, and the importance of the study. Finally, an outline of the structure of the thesis is provided.

1.2. Research motivation

My interest in exploring how to manage the risks to Egypt's water supply due to the new dam by using a multi-perspective and multi-framing approach arose from over 17 years of academic and practical experience in working on risk management techniques, accompanied by managing and leading projects working on water resource management in Egypt, along with my reflections on my university learning experiences. Albert Einstein said "I have no special talents. I am only passionately curious." I have always been curious about our contribution toward a better life for humans.

My bachelor's degree in civil engineering qualified me to work on water-related projects as a project engineer. After a few years, I was promoted to project manager, then executive manager for a consultant engineering company. A few years later, I was given a better opportunity as the general manager of one of the top engineering construction companies in Egypt. This experience and background helped me gain better and further develop management skills such as risk management techniques. Following this, I obtained a Diploma and a Master's in project management. During my postgraduate studies, I worked in different positions for Egyptian and multinational companies specialising in the risk management field, and different academic positions, which allowed me to gain more insight into water resources and risk management issues. This experience showed me the importance of managing risks involved with water resources, especially in a world with very limited and increasingly valuable water resources.

Egypt depends on the Nile to secure about 98% of the water it needs for different purposes (Abdulrahman, 2019). About 96% of this water originates outside Egyptian territory, with 86% coming from Ethiopia alone. In 2011, Ethiopia announced the construction of a new dam, called the Grand Ethiopian Renaissance Dam (GERD) at the headwaters of the Nile (Salman, 2016). The construction of the GERD will have many consequences and risks for Egypt, whose livelihood currently depends on the Nile's water (Abdulrahman, 2019). I started to realise that this constitutes a huge problem, which needs to be studied to help my country navigate this conflict and avoid its impacts as much as possible.

I noticed that the perceptions of these risks differed dramatically depending on the perspective adopted in studying them. Studies to date have analysed these risks by using one or at most two perspectives at a time. However, given Egypt's critical situation and surrounding circumstances, many perspectives must be adopted to gain a better understanding of the nature of these risks. In simple terms, reviewing past studies led me to realise the importance of studying this conflict by using a multi-perspective and multi-framing approach. I was particularly curious to know the best ways to predict and mitigate the consequences of this crisis.

I fathomed that exploring the risks of managing water resources by using different frames would give me a global perspective and a more comprehensive understanding of this issue. These frames will provide a methodological framework for other similar disputes over shared watercourses. Moreover, since I had an opportunity to do so, I took it up gladly. This is what provided the direction of my PhD research.

1.3. Purpose of the study

The purpose of this research is to explore how one might use different perspectives, frameworks, and tools to understand the nature of the studied risks to Egypt's water supply due to the construction and operation of the GERD; identify the root causes; evaluate expected risks; understand how to control, alleviate, and mitigate them; and address the implications for Egypt, focusing in particular on Egypt's agricultural sector. The Egyptian agricultural sector was selected as the focus of the research as it is considered to be one of the most affected sectors, given more than 70% of Egypt's share of the Nile's water is consumed by agricultural activities (Abdelsalam et al., 2014).

1.4. Objectives of the study

The general objective of this research is to study the risks for Egypt due to the construction and operation of the GERD, using many different frames to analyse the issues drawing on many perspectives leading to a multi-frame assessment of this conflict.

Many previous studies address the risks to Egypt's water supply due to the construction and operation of the GERD, albeit from only one perspective. However, the nature of the situation itself is so critical and complex, that using a one-dimensional view prevents an adequate understanding of the situation and its root causes and limits the options open to consideration. This study fills the research gap and presents the first comprehensive study that discusses this topic by adopting different perspectives and a multi-framing approach.

The key question of this research is, "What are the expected risks to Egypt's water supply due to the construction and operation of the GERD in general and the consequent disruption to Egypt's water supply and impacts on the agricultural sector in particular, and how can Egypt deal with these risks?" The case analysis will provide an example of how to approach international disputes over shared watercourses.

The research answers this question by using a multi-framing approach. Sub-questions that will be addressed by the various frames within the multi-framing approach are:

1) What is the nature of this situation (from each of the chosen perspectives)?
2) What are the relationships, challenges, and risks for the agricultural sector related to water supply shortages in Egypt due to the GERD construction and operation?
3) What are the root causes of the conflict (between Egypt and Ethiopia)?
4) What are the root causes of the agricultural sector problems before the expected impacts due to the GERD?
5) How can the consequences of this situation be identified, controlled, alleviated, and evaluated?
6) How a better understanding of the uncertain nature of the current situation could be gained to provide different stakeholders and decision makers with deep insights that can support their decision-making process?
7) What are the current and expected implications for Egypt due to this situation?
8) What are the suggestions for possible alternatives that when implemented could help to overcome these risks and lead to practical solutions for decision makers and stakeholders?

1.5. Road map to implementing the research framework

This study uses a multi-framing approach while taking into consideration the role of context, the nature of the international conflict and the nature of frames themselves in the framing processes, which leads to a better understanding of the conflict, allowing deep insights and proposing alternative actions.

Four main phases of implementation are involved. Phase one involves a review of the literature related to previous studies about the case and an overview that covers the chosen methodologies and approaches (Chapters 2 and 3).

Phase two is a contextual analysis of the historical frame that provides a historical context of the conflict for a full understanding of the past. This is followed by a contextual analysis of the legal position that provides legal background to clarify the legality or illegality of Egypt's and Ethiopia's actions according to different international laws (Chapters 4 and 5).

Phase three is the application of individual frames to analyse primary data gathered during field research. These frames comprise a PIM frame, decision-making trees and tables frames and a suite of TOC frames. The field study is conducted on two levels, international and local. The first level asked international experts to evaluate the situation and the conflict from their points of view, analysed using the PIM frame and decision trees and tables frames (Chapter 6). The second level provides a voice to different Egyptian stakeholders from three different categories (the government, local and industry levels) to share their views about the agricultural sector and make suggestions and recommendations for consideration (TOC frames) (Chapter 7).

Phase four is the integration of these different perspectives within a multi-framing analysis to arrive at results at macro and micro levels. The macro level looks more at the bigger picture, which is presented at the international and national levels, while the micro level is more concerned with details of the agricultural sector itself and interactions between individuals. This enables the researcher to address the complexity of issues resulting from the study context, and illustrate the insights arrived at through the use of complementary approaches and tools in the multi-framing study (Chapters 8 and 9).

1.6. Importance of the study

The significance of this research is its originality and contribution.

Originality

This research is original as the expected risks from constructing and operating the GERD on Egypt, have not been analysed by using multi-perspective analyses using a multi-framing approach before. Moreover, some frames have not been used at all, even individually, in comparable situations.

Contributions

The study makes theoretical, methodological, and practical contributions.

Using the multi-perspective and multi-framing approach is in itself a theoretical contribution given that no previous studies, related to this case, have adopted multiple frames. A very limited evaluation of the case was developed due to the limited and unidimensional analyses of the situation. This study benefits from using a multi-framing approach to analyse the complex situation in Egypt, which enabled more comprehensive analysis and offered a broader range of solutions. Another theoretical contribution is the development of a new tool of the TOC TPs, which the researcher expects to have wide applicability for users of the TOC TPs worldwide who wish to tackle increasingly pressing global issues. This development also constitutes a methodological contribution.

Methodologically this study adds to the body of multi-framing knowledge. The choice of frames is unique, with each one being chosen to suit a specific purpose and evaluated in a specific sequence. Moreover, this choice also suits the situation and the researcher's expertise. This would appear to be the first time this methodological framework has been used to study disputes between countries over shared watercourses. It provides additional insights through past, present, and future situations of the dispute in question and offers a template for studying other similar international disputes over shared watercourses and other shared natural resources.

As its practical contribution, this study leads to different findings, which would provide benefits for decision makers, stakeholders, and the Egyptian government. The multi-framing approach can provide a platform for finding practical solutions and suggestions for better use of the currently available amount of water; makes suggestions to enhance the agricultural and water practices; makes suggestions related to new water resource alternatives and new agricultural techniques to increase the efficiency and sufficiency of crops, among many other suggestions. The study contains recommendations to adopt new plans at different levels and aspects, which will benefit Egyptian stakeholders and decision makers.

1.7. Structure of the thesis

The thesis takes the form of nine chapters, namely:

Chapter 1: Introduction

This chapter discusses the motivation of the study and outlines the aims and objectives. The research gap and questions are defined. The significance of the study, including its originality and theoretical and practical contribution, is also explained.

Chapter 2: Background and literature review

It begins by laying out the theoretical dimensions of the research and a review of the literature within this scope. This sheds light on the general profile of the Nile in general and the case under study in particular; a review of Nile's water dams; the GERD; the characteristics of the GERD case study, unit of analysis of the case study (agriculture), and a discussion of the risks associated with the GERD. It also explores the prior studies on the risks associated with the construction and operation of the GERD on Egypt. The chapter aims to highlight the gaps in the literature.

Chapter 3: Research methodology

In the third chapter, a detailed discussion of the research methodology is provided. This includes the research paradigm and research design, the perspectives of complexity, and the multi-framing approach used to explore how to manage the risks to Egypt due to the GERD's construction. In addition, an explanation of the four different perspectives, historical, legal, risk, and TOC, was provided. Some of these perspectives use different frames/tools, such as PIM, decision trees and decision tables as frames for the risk perspective and a suite of six TOC frames (TOC 5FS and TOC TP tools (Goal Tree (GT), Current Reality Tree (CRT), Evaporating Cloud (EC), Future Reality Tree (FRT), and Prerequisite Tree (PRT)), which attempt to capture systems complexity and systemic relationships. The ontology and epistemology related to each of the frames are discussed. Moreover, the chapter provides the readers with a description of the approaches used to collect the primary data through interviews and the approaches used for data analysis. Validity checks and ethical considerations are also explored.

Table 1 summarises the perspectives and frames used in this study covered in the four analysis chapters.

Chapter	Perspective	Frame
4	Historical	Historical analysis
5	Legal	Legal analysis
6	Risk	PIM
		Decision trees
		Decision tables
7	TOC	TOC TPs
		TOC 5FS

Table 1: Different perspectives and frames for the study.

Chapter 8: Discussion of findings

This chapter provides a discussion of the findings guided by research objectives, and in relation to gaps identified in the literature review. The chapter also offers an illustration of the highlights and shadows of each frame. It also addresses their integration at both micro and macro levels.

Chapter 9: Conclusion and recommendations

This concludes the thesis with a summary of key findings and outcomes. The chapter also offers possible resolutions and recommendations, which are suggested by the researcher. This chapter highlights the theoretical and methodological contributions and practical implications of this case analysis. Limitations and further research are outlined, along with personal reflections of the researcher and concluding remarks.

Chapter 2
Background and Literature Review

2.1. Introduction

Human knowledge is created by building ideas on each other and extending old theories by identifying and developing new perspectives from previous research. This chapter presents a literature review concerning water supply shortage risks to Egypt caused by GERD. The objective is to provide a broad understanding of the chronic dispute over the Nile River and its use. The chapter starts by shedding light on the importance of the Nile to ancient Egypt. It is followed by the Nile's geographical background, which includes a general profile of the Nile and its water dams. Then, the literature about the case under study is reviewed. This part provides information related to the risks associated with the construction of the GERD and the characteristics of this case study. Finally, based on gaps identified in the literature review, a conceptual multi-framing approach, adopting different perspectives of complexity, is proposed to fill the gaps that this study addresses.

2.2. The importance of the Nile River to ancient Egypt

Human beings have lived along the Nile's banks for over 5,000 years (McKenzie, 2012). According to Conniff (2017), the Ancient Egyptian civilisation was founded along the river thousands of years ago, as evidenced in ancient sites including temples and other constructed dwellings.

The ancient Greek historian Herodotus, in the fourth century BC, stated "Egypt is the gift of the Nile", meaning that Ancient Egypt owed its survival to the Nile. Civilisation began in Ancient Egypt because of the resources of the great river (Ibrahim, 2010). Egyptians have always had an emotional relationship with the Nile, much more than any of the other Nile basin States (Tafesse, 2011). For Egyptians, the Nile remains a centre of social life, an endless source of pleasure, discovery, and the source of deeply rooted Egyptian traditions (Gad, 2008), as shown in many pharaonic pictures on the famous temples and statues.

Gemmill (1928) adds that Herodotus was not exaggerating when he said 2,500 years ago "Egypt is the Nile, and the Nile is Egypt". In times of famine, Egypt provided ancient Judea tribes with grain. In Roman times, Egyptian grain was exported widely, including to Europe. Later, Egypt became the granary of needy people. Nowadays, the only fertile areas in Egypt are the Nile Delta and Valley. (Gemmill, 1928).

The Nile was worshipped as a god in ancient Egyptian civilisation. They called it "Hapy". Hapy appeared in the shape of a very fat man with enormous breasts and green or blue-coloured skin as a sign of fertility. The decoration of Egyptian temples included drawings of Hapy holding fertility signs that represent the famous production of each Egyptian district (Pinch, 2004). El-Sawi (1983) adds that Hapy was also represented in two other forms on the walls of some temples. In these forms, Hapy has a normal body, wide shoulders, and slim hips. The normal human head of Hapy is replaced by two heads, one looking forward, while the other looks backward, both heads have goose necks. The two forms of Hapy differ in that one carries a papyrus plant on his head while the other carries a lotus plant. These two forms represent the two Nile gods, the South and North Nile gods. In these drawings, Hapy wears the gods' usual costume, a white tight short skirt and yellow overwrap, and his skin is a greenish-blue colour.

An ancient myth says that the Nile's flood came from two caves. These caves were the imprints of the creator's sandals. The god Khnum is responsible for these two secret caves. The myth also says that all creatures feel joyful and cheerful because of Hapy (flood) arriving. The roaring of the crocodiles, the croaking of frogs and the bellowing of bulls represent this joy. Lord of Fish and the Barley and Wheat Maker are other names for Hapy (Pinch, 2004).

Religious songs, hymns and chants provide further indications of the Nile's significance for ancient Egyptian civilisation. Hymns were written to thank the creator for his gift of the annual floods which enable the irrigation of the lands. Consequently, it affected the life and food that Egyptians counted on (Pinch, 2004).

Bell (1970) points out that Egyptian rainfall is very rare and infrequent, which forced Egyptian farmers to completely depend on the annual Nile flood for at least 5,000 years. Before the construction of modern dams, the flood was responsible for the irrigation and preparation of the soil for agriculture. Some years it brought plenty of water, while dry years resulted in famine. Bell (1970) observes that the ancient Egyptian civilisation is also known for its astonishing and stupendous achievements. One of these achievements is the royal annual measurement record for the maximum height of the Nile's flood. Archaeologists found one of these records engraved on a stone plaque, dated to the Fifth Dynasty in the 25th century BC. This record contained annual immersion levels in the First Dynasty about 3,050 BC, in the reign of King Zer (Djer). These records are indicators of the Egyptians' obsession with the Nile.

The Nile also played a major role as the link between Europe and Africa. In the 15th century, the Nile attracted explorers and adventurers from Europe. Later, the Nile paved the way for European expansionism and colonialism. European domination continued until the mid-20th century (Nicol & Shahin, 2003).

The Nile basin was a fertile ground for thriving civilisations and cultures, reflecting the uniqueness of this region. This rich archaeological territory was one of the factors that gave the Nile its global significance. A great effort in the mid-1960s went into saving archaeological sites in Lower Nubia in the territories of Egypt and Sudan before the construction of the Aswan High Dam and the creation of Lake Nasser immersed the region. UNESCO's 1959 international appeal provided funding to save this ancient heritage. This massive effort took years and resulted in the saving of beautiful and priceless artefacts and remains of the ancient civilisation, such as Abu Simbel temple (Nicol & Shahin, 2003).

2.3. The geographical background of the Nile River

A general geographical profile of the Nile is provided in this section. This includes the most important dams constructed along the Nile. Moreover, it explains the specific details of the GERD case.

2.3.1. General profile

The total amount of water on earth is estimated at 1.386 billion km^3, in which about 97% is salt water that is unsuitable for human consumption. The remaining 3% is considered freshwater. However, the availability of this 3% is questionable for different reasons, including: water being captive in deep aquifers, water imprisoned in icecaps, or water being polluted. Consequently, about 87% of this 3% of freshwater is not accessible (Toset et al., 2000). The geographical distribution of the world's water resources is unequal and uneven worldwide (Gleditsch et al., 2006). River basins provide 60% of the freshwater supply globally. The water of these basins could be a cause for disputes, or a catalyst for peace and collaboration (Giordano et al., 2014).

Water resources are challenged by factors such as: climate change, the dramatic increase in population, environmental deterioration, manufacturing activities and urbanisation. Eventually, this leads to water deficiency, which affects the global situation and creates disputes over water as a logical consequence (Salman, 2007).

The Nile is one of the longest rivers in the world. It flows about 6,650 km from its sources in the south, Ethiopia, and Uganda, to the Mediterranean Sea in the north (Salman, 2013a). The Nile basin includes eleven countries: Burundi, the Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. The Nile basin's drainage covers an area of 3,254,555 km^2, which represents 10% of the total area of Africa (Abdulrahman, 2019).

The Nile has two major tributaries, the White Nile, and the Blue Nile. The first flows from the equatorial lakes of the east and centre of Africa, the most important of which is Lake Victoria. The area of Lake Victoria is about 43,130 km2. The lake is fed by direct precipitation and by thousands of tiny streams in Tanzania, Uganda, and Kenya. The other tributary, the Blue Nile, flows from Lake Tana in Ethiopia (Abdulrahman, 2019). The Blue Nile and White Nile combine in Khartoum, Sudan, to form the main body of the whole Nile, which then flows directly through Egypt into the Mediterranean Sea (Paisley & Henshaw, 2013).

Salman (2011) classifies the eleven basin States into four categories based on the intensity of their interests in the Nile. Egypt, Sudan, South Sudan, and Ethiopia are classified as having very high interests; Uganda is high; those of Tanzania, Kenya, Burundi, and Rwanda are moderate; and those of Eritrea and the Democratic Republic of Congo are low.

Figure 1: The Nile basin States with the GERD highlighted in red (Abdulrahman, 2019).

Egypt is highly dependent on the Nile to secure 98% of its water for different purposes (Abdulrahman, 2019). This makes Egypt the main consumer of the Nile's water (Salman, 2013a). About 96% of the water reaching Egypt originates outside its territory (Hefny & Amer, 2005). About 86% of the Nile's water reaching Aswan on the southern border of Egypt originates in the Ethiopian Plateau, comprising 62% from the Blue Nile and the rest from the Tekezze/Atbara and Baro-Akobo-Sobat Rivers (Sadoff, 2006). The remaining 14% is provided by the White Nile (Salman, 2013a). Tafesse (2011) claims that the Ethiopian contribution to the Nile's flow could increase to 95% during the heavy summer rainy season from July to September. Egypt and Sudan have historically used almost the entire flow of the river, with Ethiopia using less than 1% of the flow until recently. Disputes over the Nile basin started because of the inequity of usage of some countries (Salman, 2013a). Tafesse (2011) questions the justice of this allocation.

McKenzie (2012) makes a geographic comparison between the Nile and other rivers. He states that the magnitude of the Nile allows it to be considered a main river system; however, in comparison with rivers of the same size, it transfers much less water than they do. McKenzie (2012) states that the Nile carries about 6.5% of the water of the Congo River and 3% of the Amazon River. Therefore, McKenzie (2012) concludes that as the Nile's basin States have less water to share, eventually this would raise tensions and create disputes over its water.

The dramatic growth of the basin population is escalating the situation rapidly. According to Abdelhady et al. (2015), the population of the 11 basin States is more than 370 million inhabitants, while Salman (2013a) predicts that this figure is expected to reach 500 million by 2030.

In 2018, the annual per capita share of water in Egypt was 570 m^3/year, well below the recommended international standard of 1000 m^3/year. This constitutes a case of chronic water scarcity (The Egyptian Ministry of Planning and Economic Development, 2021). Forecasting for the year 2025 predicts this rate to fall under 500 m^3/year because of the expected Egyptian population growth, which presages an absolute scarcity case (Hefny & Amer, 2005).

About 90% of the Egyptian population lives in a narrow strip of land along the Nile's Banks (McKenzie, 2012). Egypt's population is currently estimated to be about 101 million (CAPMAS 2021) and it is forecast to reach 153 million by 2050 (Abdulrahman, 2019). Conniff (2017) notes that most of the Egyptian cities are established around the banks of the Nile and Delta, a triangular area where the Nile is divided into two branches. The total area of the Delta and the Nile valley together form 3.5% of the Egyptian total lands. It is estimated that 45 to 50 million live in the Delta, 2.5% of Egypt's total land, while the rest of the population lives in the Nile valley on 1% of Egypt's total land (Conniff, 2017).

Nile water availability is a matter of life and death for Egyptians (McKenzie, 2012).

2.3.2. The Nile River's water dams

Salman (2016) indicates that the Nile's dam construction began in 1894 with the first Aswan Dam by the British government, which was completed in 1902. At the time, it was the biggest dam in the world. It was enlarged in height twice to double its storage capacity, in 1908 and 1933. Later Egypt constructed a series of barrages at Essna, Naga Hammad, Assuit and Edfina to control the water to maximise its benefits in irrigation.

The Egyptian government decided in 1956 to construct an even bigger dam (Moussa et al., 2001). Following the 1959 Treaty between Egypt and Sudan (see chapter 4), construction of the Aswan High Dam (AHD) commenced in 1960 and was completed in July 1970 (Salman, 2016) The dam officially began operation in January 1971. The capacity of the dam's reservoir is 162 billion cubic metres (bcm).

Mossallam (2014) claims that AHD arose from unique circumstances. The World Bank (WB) and its Western affiliates withdrew their initial offer to finance the dam as a form of political coercion, which led Egypt to turn to the Soviet Union for funding technology to build the dam (Salman, 2016). The Egyptian response was part of its long battle against imperialism which led to its engagement in the Cold War by choosing Soviet support to avoid risking a war following its nationalisation of the Suez Canal (Mossallam, 2014).

Sudan constructed its first Blue Nile dam, the Sennar Dam, in 1919 (completed in 1925) for the Gezira irrigation scheme. According to water law conventions of the time, Sudan needed Egyptian approval for constructing the Sennar Dam. However, to get this approval, the Anglo-Egyptian administration in Sudan approved the construction of the Jebel Aulia Dam on the White Nile in Sudan for Egypt's exclusive benefit (Salman, 2016). This was the first occurrence of a dam being built entirely in one country for the benefit of another. Jebel Aulia Dam reserved 3.5 bcm of the water of the White Nile during the flow season of the Blue Nile and freed this water for Egyptian use when the waters of the Blue Nile reduced (Salman, 2016). Construction of the Jebel Aulia Dam started in 1933 and finished in 1937. It was the first White Nile dam. The AHD removed Egypt's need for the Jebel Aulia Dam, and it was returned to the Sudan in 1977 (Salman, 2016).

Under the Egyptian-Sudanese Treaty (1959), Egypt permitted the Sudan to build the Roseiris Dam on the Blue Nile to irrigate the Managil extension, in exchange for Sudanese permission to Egypt to construct the AHD. Later, Sudan constructed the Khashm Algirba Dam, which was finished in 1964. The Merowe Dam was constructed by Sudan (completed in 2009) on the main Nile predominantly for generating hydropower (Salman, 2016).

Following many rounds of negotiations that led to several agreements between Egypt and Britain (representing Uganda), Uganda started the construction of its first dam, Owen Falls, in 1940. This dam was constructed across the White Nile near its source at Lake Victoria and was completed in 1953 for the main purpose of generating hydropower. A further dam – Bujagali was constructed for the same purpose and was completed in 2012. Uganda is currently working on many studies for the construction of other dams on the White Nile (Salman, 2016).

Ethiopia was the last country of the Nile basin to begin dam building. Fincha Dam (completed in 1973) was constructed by Ethiopia on the Blue Nile to generate hydropower. It was followed by three small dams for this same purpose, the last being the Tekeze Dam (constructed 2002-2010). Constructing these dams motivated Ethiopia to challenge the Nile's treaties. However, in March 2011 Ethiopia declared its intention to construct a new dam – the Grand Ethiopian Renaissance Dam (GERD) - on the Blue Nile (Salman, 2016). While Egypt had expressed no objections to Ethiopia's earlier dams, the situation was quite different with the GERD.

2.3.3. The profile of the Egyptian and Ethiopian water resources and consumption

A profile of Ethiopia's and Egypt's access to, and consumption of, water is provided using the concept of virtual water. Virtual water is defined as the amount of water consumed to create a product, separated into three different types, green, blue, and grey water. Green water is the water that comes from rainwater that is stored in soil and plant roots. Blue water is the surface water that flows through water bodies and groundwater, while grey water is the waste water polluted through usage, which needs to be sent to treatment plants to reach an acceptable quality for reuse (Clothier et al., 2010). In this study, green water is represented by rainfall. Blue water is represented by rivers (especially the Nile), lakes, and groundwater resources. Grey water is represented by recycled/reused water.

Ethiopia's access to water resources can be described as "generous", with several major rivers, lakes, groundwater, and high annual rainfall. Twelve major basins supply 124.4 bcm of water annually. Twelve large lakes contribute 70 bcm of water, while groundwater resources comprise 30 bcm. The 12 main basins are divided into 8 river basins, 3 dry basins without a significant flow, and 1 lake basin (Berhanu et al., 2014). In the heart of Ethiopia's territory is a wide highland contributing to the system of three main rivers, namely the Nile, Awash, and Omo. Moreover, Ethiopia contains the upper headwaters of three rivers, the Nile, the Gash, and the Juba-Shebele. The four main river basins are home to about 40% of Ethiopians and supply nearly 90% of Ethiopians' water. The other 60% of the population, who depend on less than 20% of the Ethiopian water resources, live in the eastern and central river basins. Ethiopia is home to more than 15 natural lakes, of which the biggest, Lake Tana, has a total area of 3600 km^2 (Sadoff, 2006).

At the downstream end of the Nile River, Egypt has a completely different water availability and consumption profile. Egypt's water resources are very limited, amounting to 67 bcm annually. The main water source is the Nile which contributes 55.5 bcm annually. Another three resources contributing to Egypt's water are recycled/reused water, groundwater, and rain. They contribute annually 9 bcm, 2.7 bcm, and 0.3 bcm respectively. According to these numbers, the Nile contributes 82.2% of the Egyptian annual water resources, while 13.4% comes from recycled/reused water, 4% from groundwater, and 0.4% from rain. Most of the Egyptian population lives along a very narrow strip by the banks of the Nile and the Delta. The Delta is a triangular area that represents 2.5% of Egyptian land where the Nile divides into two branches and reaches the Mediterranean Sea. Almost half of the Egyptian population lives in the Delta (Abdelsalam et al., 2014).

The average annual rainfall in Ethiopia is about 848mm/year yielding 936 bcm annually (AbuZeid, 2020). Ethiopia depends on the Nile's water (blue water) to generate hydropower with 3 existing dams, while it depends on green water (direct rainfall) for consumption uses and for rainfed agriculture to produce food (AbuZeid, 2020). Ethiopia owns the largest population of livestock and draft animals on the African continent, estimated to include 57 million cattle, 30 million sheep, 23 million goats, 57 million chickens (FAO, 2019), 8.6 million equines, and 1 million camels (Ayele et al., 2003). This huge population of livestock feeds on rainfed grazing lands. Moreover, this livestock consumes 84 bcm of virtual water annually, which is the hidden water in natural rainfed (green water) feed and fodder. Ethiopian livestock's water consumption represents 6 times the water consumption required for Egypt's livestock (AbuZeid, 2020). According to the World Bank data in 2018, the total Ethiopian agricultural land is estimated at 379,030 km^2 (37.9 million hectares), which represents 33.6% of the Ethiopian land. The percentage of agricultural irrigated lands is estimated to be about 2.1% of the total Ethiopian agricultural lands, which means that about 97.9% of Ethiopian agricultural activities depend on green water (WB, 2018).

In stark contrast, Egypt is classified globally as the country with the lowest rainfall rate at 18.1 mm/year, while the average annual rainfall is estimated at 0.3 bcm annually. Egypt depends on the Nile (blue water) to supply most of its water needs, especially irrigation for agriculture. Egypt owns 19 million heads of livestock that consume 14 bcm annually of virtual water hidden in irrigated feed (blue water) and (mostly imported) fodder. The Egyptian consumption represents one sixth of Ethiopian livestock water consumption. In addition, Egypt imports most of its meat and livestock products, due to its lack of water, as well as some important crops.

Egypt is considered the biggest importer of wheat in the world (AbuZeid, 2020). The total Egyptian agricultural land is estimated at 38,359 km^2 (3.8 million hectares), which represents 3.85% of total Egyptian land (WB, 2018). Egyptian agricultural activities alone consume 70% of Egypt's share of the Nile's water (Abdelsalam et al., 2014), which means that most Egyptian agricultural activities depend on the Nile blue water.

To summarise, a comparison between the availability and consumption of water resources in Ethiopia and Egypt is provided in Table 2.

Item	Details	Ethiopia	Egypt
Water resources	Major water resources	• Twelve major basins supply 124.4 bcm/year. • Twelve large lakes contribute 70 bcm/year.	The main water source is the NR, which contributes 55.5 bcm/year.
	Groundwater and recycled/reused water	Groundwater resources comprise 30 bcm.	• Recycled/reused water contributes 9 bcm/year. • Groundwater contributes 2.7 bcm/year.
	Rainfall rate	848mm/year	18.1 mm/year
	Average annual rainfall	936 bcm/year	0.3 bcm/year
Livestock	Population of livestock and draft animals	57 million cattle, 30 million sheep, 23 million goats, 57 million chickens, 8.6 million equines, and 1 million camels.	19 million head of livestock.
	Livestock feed resources	Feeds on the rainfed grazing lands, which are irrigated by green water (rain).	Feeds on irrigated lands, which are irrigated by blue water (NR), and mostly imported fodder.
Agriculture	Total agricultural lands	379030 km^2, (37.9 million hectares) represents 33.6% of the Ethiopian lands.	38,359 km^2 (3.8 million hectares) represents 3.85% of the Egyptian lands.
	Percentage of the agricultural lands that are irrigated depending on blue water (NR, rivers, lakes)	About 2.1% of the total Ethiopian agricultural lands	Agricultural activities alone consume 70% of Egypt's share of NR's water
	Percentage of the agricultural lands that are irrigated depending on green water (rain)	About 97.9% of the total Ethiopian agricultural lands	Almost none.

Table 2: A profile of the Ethiopian and Egyptian water resources and consumption (Youssef et al., 2022).

2.3.4. The Ethiopian Grand Renaissance Dam (GERD)

The GERD is located 700 km northeast of Addis Ababa, the Ethiopian capital, which is in the Benishangul-Gumaz region. It is a state-owned project, for the Ethiopian Electric Power Company. Ethiopia has declared that the main purpose of the GERD is to generate hydropower, and they have no intention to use this dam for irrigation purposes (Pietrangeli et al., 2017).

Electricity generated will serve both Ethiopian and export demands. First, it is expected that this hydropower would cover Ethiopian needs, including domestic use as well as many of the industrial production activities and other electricity-dependent sectors, which will promote economic development and Ethiopian wellbeing. Second, Ethiopia is obligated to sell a portion of the generated hydropower to other countries due to signed contracts, which in return helps in supporting Ethiopian economic development. This hydropower is also expected to be exported and benefit the whole Eastern and Southern Africa region (Tesfa, 2013).

Italian consultant Studio Pietrangeli is the designer and main provider of the engineering and consultancy services, while the main contractor is Salini-Impregilo SpA. The GERD is estimated to be the 80th largest dam in the world and the largest hydropower dam in Africa (Abdulrahman, 2019). The dam's height is about 175 metres (m), with a length of 2 kilometres (km). The total quantity of reinforced cement concrete is estimated to be 10.2 million cubic metres. The dam's plant has 16 turbines designed to generate 6,000 Megawatts of installed power and annual energy production evaluated at approximately 15.7 Terawatt-hour. (Pietrangeli et al., 2017). This dam was first named the Millennium Dam, but later, Ethiopia changed its name to the GERD. The GERD's reservoir can hold more than 74 bcm of water (Salman, 2016).

The project has also drawn headlines for other reasons. Engineer Simegnew Bekele the GERD's former project manager and chief engineer was found dead in his car on 26 July 2018. The Ethiopian Federal Police, Commissioner Jemal Zeinu, announced that Bekele was shot in his car in the Meskel Square area, in Addis Ababa. Zeinu stated that Bekele was holding a gun in his right hand (The Ethiopian News and Informed Opinion, 2018). The Ethiopian News and Informed Opinion (2018) claimed that Bekele was holding a meeting with journalists on the same day to discuss the progress of the GERD. The strange circumstances surrounding his death have aroused suspicion that it may have been an assassination rather than suicide.

Furthermore, the Ethiopian Prime Minister, Abiy Ahmed, announced in a gathering with lecturers from across the country a week before Bekele's death that the GERD project would need up to ten years to be finished (The Ethiopian News and Informed Opinion, 2018). Maasho (2018) claims that the GERD project faces some challenges because of execution problems. Maasho (2018) adds that the Ethiopian Prime Minister announced in August 2018 that Ethiopia cancelled the Metals and Engineering Corporation's contract and would award it to another company. METEC is Ethiopia's largest military-run industrial complex. METEC was the electromechanical and hydraulic steel structure subcontractor for the GERD.

The dam's cost is estimated at US$4.8 billion, which will be paid by the Ethiopian government (Salman, 2016). The WB refused to fund the project because of the expected objection by the downstream countries due to the risks and tensions raised (Abdulrahman, 2019).

It is expected that the GERD would have different consequences for both Sudan and Egypt as downstream countries. However, they would be differently affected due to their different needs for water, different uses, and different economic positions.

For Sudan, the GERD will bring benefits. These include discharging sediment, which is carried annually by the Blue Nile to the Sudan. The sediment occupies more than half the storage of the two Sudanese dams (Sennar and Roseiris) and affects their ability to generate hydropower (Salman, 2016).

The GERD will help in regulating the Nile's flow, which will prevent floods, and stop the destruction of property and crops. This regularity of flow will also help Sudan to increase crop rotations to two or three a year, which would increase Sudanese agricultural production. This would also help the replenishment of groundwater throughout the year (Salman, 2016).

Salman (2016) also claims that Sudan could store some of its Nile shares in the GERD reservoir, after forming an agreement with Ethiopia. Buying cheap electricity from Ethiopia is another potential benefit for Sudan.

However, two concerns for Sudan due to the GERD are the dam's safety and the annual operation of the GERD, which could affect the filling time of the Sudanese dams. In light of the above, the Sudanese position is in favour of the dam (Salman, 2016).

For Egypt, the situation is totally different as will be explained in the next section.

2.3.5. The expected consequences associated with the GERD on Egypt

There is an urgent need to address the consequences associated with the GERD to understand the nature of these studied risks to Egypt. These risks and their consequences are an important, but understudied, cause for concern.

Positive risks (opportunities)

On the one hand, some scholars debate the positive expected side effects of the dam on Egypt (Tesfa, 2013; Mulat & Moges, 2014).

- Positive effect on reducing sedimentation
  Tesfa (2013) claims that based on the GERD's technical design and quantitative analysis, it is expected that the GERD would eliminate about 86% of Egypt's bad silt and sedimentation. Reducing the quantity of silt would improve the stability of the water flow. Moreover, the elimination of sedimentation would help in stabilising the production of hydropower in the downstream countries. Decreasing these sediments would reduce the costs of hydropower stations maintenance, and the cost of maintaining and cleaning the irrigation channels. Ramadan et al. (2013) explain that it is estimated that 50% of the sediment at

Aswan comes from the Blue Nile. They agree that the GERD could help in reducing sedimentation and increasing the lifetime of the downstream infrastructure water projects. This reduction could also help in raising the active storage capacity of the AHD's reservoir.

- Water conservation

  Water conservation is another benefit that could be achieved, if Egypt and Sudan, in cooperation with Ethiopia, decide to store more water in the GERD's reservoir rather than the reservoirs of the Egyptian and Sudanese dams. The reservoirs of the Egyptian and Sudanese dams are in desert areas, which have a very high evaporation rate. The evaporation rate in the GERD's area will be less than the downstream countries' desert areas because of the difference in geographical and weather characteristics. The GERD is expected to maintain water in the Ethiopian highlands (Tesfa, 2013).

  According to Tesfa (2013), constructing a reservoir is one of the known approaches that people can use to mitigate extreme hydrological events. He adds that the GERD would alleviate the adverse impact of droughts and floods by controlling the headwaters of the Nile.

  Mulat and Moges (2014) agree with Tesfa (2013) about the capability of water conservation in the case of cooperation between the two countries. They comment that retaining more water in the GERD's reservoir while operating the AHD at a lower level would decrease the evaporation rate of the AHD in comparison with the current situation.

- Minimal effect on generating hydropower from the AHD

  A simulation model was used to study the GERD's effects on generating hydropower electricity from the AHD in Egypt. It is expected to have a minimal effect if Ethiopia fills the dam's reservoir over a period of six years or more. This would decrease the output of the Egyptian hydropower by only 12% annually during the filling phase, and by 7% annually after the filling phase. However, the overall performance of the AHD would be maintained at a reliable level during and after the filling phase (Mulat & Moges, 2014).

  Mulat and Moges (2014) claim that the water's withdrawal from the AHD for Egyptian agricultural purposes would not be affected, although the water's flow would be reduced by 19% during the assumed six years of filling time. Moreover, the decrease in the storage volume of the AHD's reservoir would not reach the minimum level that could affect its operation. They add that Egyptian hydropower production would not be enormously affected in relation to the reduction of the water's annual flow and the amount of water discharge. From a regional point of view, they found that managing the GERD and AHD dams together would increase the hydropower production of the region.

- Regularity of the flow

  The GERD would affect the regularity of the Nile's flow across the year. The seasonal Blue Nile's flow distribution would be more uniform and thus, beneficial to flood control for downstream countries. It is expected that flow reaching the AHD would increase from November to June and decrease from

July to October. However, the study also shows that the water level reaches its minimum operational level for some months. Meanwhile, there would be water deficiency at the AHD, which would potentially cause a 7% decrease in hydropower production after the filling phase (Mulat & Moges, 2014). However, the authors advise care when using the results of their study because it depends on one possible scenario which may not be what eventuates.

Negative risks (threats)
On the other hand, many researchers discuss the expected negative risks of the GERD's construction and operation on Egypt (Abdulrahman, 2019; El Bedawy, 2014; Conniff, 2017). El Bedawy (2014) strongly believes that the GERD's specifications would expose Egypt to large risks. Abdulrahman (2019) affirms that because of the GERD, the Nile would never come back to current levels, which would eventually affect Egyptian economic performance. El Bedawy (2014) proposes that the GERD would not only affect Egypt's economy but would also interrupt Egypt's development plans. Similarly, Stanley and Clemente (2017) agree that the GERD would accelerate the serious problems of water and energy poverty in the downstream countries.

- Reducing the Nile's flow and decreasing the amount of water available to Egypt
  Abdulrahman (2019) argues that the GERD will diminish the Nile's flow. The impact of the GERD will not be limited to the filling time of its reservoir in the short term but will continue to affect the Nile in the long term. Abdulrahman claims that this dam will give Ethiopia the power to take control of the Nile's water. This control is anticipated to have a catastrophic long-term effect on the downstream countries, especially in the absence of cooperation. There are additional circumstances that would not help in maintaining the regular level of the Nile in the long term such as the vaporised water from the GERD's new reservoir and climate change (Abdulrahman, 2019).

  Some of the expected risks are due to the reduction of the water level in the Nile and the decrease in the water available to Egypt (El Bedawy, 2014). The decrease will affect water availability for human use and agricultural and industrial uses. Therefore, this will affect water costs as well (Abdulrahman, 2019).

- Effect on cultivated lands
  The shrinkage of the cultivated lands is also one of the main expected side effects of the predicted decrease of the Nile's water (Abdulrahman, 2019). El Bedawy (2014) illustrates that the GERD will cause a huge shortage of the Egyptian water share relative to the current share. This shortage will eliminate any possibility of future Egyptian agricultural expansion with a huge possibility of decreasing cultivated lands. Conniff (2017) makes a similar point on the critical situation of agriculture in the Delta. He clarifies that 60% of the Egyptian agricultural products are produced in the Delta, which will be severely affected by the shortage of irrigation water.

  In his statement, in 2013, the Egyptian Minister of Water Resources and Irrigation expressed his fears of the consequences of filling the GERD's reservoir in six years. He said that it will cause a 12 bcm reduction of the Nile's flow reaching Egypt per year, in the case of the assumed six years. This proportion represents about 23% of the annual Egyptian share of the Nile's water (Ramadan et al., 2013).

- Generating hydropower from the AHD

  The previous section showed that the effects of the GERD on generating hydropower from the AHD will be minimal if filled over a period of six years or more (Mulat & Moges, 2014). However, the Egyptian Minister of Water Resources and Irrigation said that the GERD will affect the generation of electricity from the AHD, if filled in a shorter period. The Minister explained that Egypt already suffers from a shortage of water and electricity supply. This situation will be made worse during and after the filling of the GERD's reservoir, especially in drought seasons (Ramadan et al., 2013).

  Stanley and Clemente (2017) expect that 25% of the Egyptian water share will be cut during the filling time of the GERD's reservoir, which will result in a loss of one third of the hydropower generated by the AHD. The annual Egyptian amount of water in the Nile is evaluated to be approximately 70% of the Nile's total flow. They predict that a big part of this Egyptian share will now be reallocated. Likewise, Conniff (2017) holds the same view as Stanley and Clemente regarding the water and hydropower losses, whilst El Bedawy (2014) estimates a 20% reduction of the hydropower generated by the AHD due to water reduction.

  It is worth mentioning that until recently Egypt was depending on the AHD to generate a big percentage of the Egyptian hydropower. This changed in the last few years as the hydropower generated by the AHD now contributes only a small percentage of Egypt's electricity supply.

- Environmental impacts

  Ramadan et al. (2013) investigated the environmental impacts of the GERD on Egypt by using a mathematical model based on historical river flow at Aswan from 1870 to 2006, which ranges from 55 bcm to 135 bcm. Four different operational scenarios of holding the water for filling the GERD's reservoir were considered: normal flow, assuming 6 years of the GERD's reservoir filling time, 3 years, and 2 years. Table 3 summarizes the results of the amount of water that will be reduced based on different scenarios of filling time of the GERD's reservoir, all numbers are in bcm.

The base scenario	Amount of water reduced in case of filling time of 6 years	The case of filling time of 3 years	The case of filling time of 2 years
The case of normal flow (about 90.7 bcm annually)	13.29	25.41	37.26
The case of minimum flow (about 55 bcm annually)	25.96	37.81	45.11

Table 3: Different scenarios of filling time of the GERD's reservoir and the corresponding water reduction.

The study also indicated that under the GERD, evaporation losses will increase by 5.9%, which will affect the Nile's water quantity and quality, and will increase the water salinity in downstream countries (Ramadan et al., 2013).

El-Nashar and Elyamany (2018) explain that the Nile's flow velocity will decrease with the GERD. This will impact water quality, which in turn will affect the efficiency of pump stations. This will also impact the water's surface profile.

Moreover, salinity intrusion in the northern part of the Egyptian Delta will increase, leading ultimately to the collapse of canals and drains, and ecological destabilisation in the north of Egypt, Alexandria, and the north coast. Increasing salinity will increase the costs of drinking water provision and reduce available cultivated lands. Adopting higher-cost undesirable alternatives such as waste water treatment and seawater desalination plants may become necessary (Abdulrahman, 2019). In contrast, El Bedawy (2014) claims that these solutions could be unaffordable for developing countries that suffer poverty and debt. This status could lead them either to use untreated water or to limit their use of existing water. El Bedawy (2014) also identifies that the GERD would affect the navigation of the river.

- Problems related to irrigation, water stations, and navigation

  Sadek (2012) used historical flow data and simulation to show that the Egyptian water share would be decreased because of the GERD. Simulation models have been used by Ismail (2013) also to show the expected negative risks on the irrigation pumping stations along the Nile in Egypt under various flow reduction scenarios.

  El Bastawesy et al. (2015) addressed the GERD's impacts on the annual net flow of the downstream States using hydrological scenarios to evaluate the GERD's lake storage amount. They showed that Egypt would be most seriously affected in drought and low-flood seasons. Lower holdings in Lake Nasser would affect electricity generation from that dam. It would be impossible to continue to supply the water needs to the Nile Valley and Delta in Egypt if lake levels lowered.

  Abdelhaleem and Helal (2015) used a simulation model to evaluate the effects of the water shortage on Egypt. They showed that the maximum allowable reduction of the Egyptian flow that could be afforded with the least damage could not exceed 15% of the annual share. Decreasing the Egyptian water share by more than 5% could affect safe navigation, while a reduction of more than 10% could affect irrigation and industrial pump stations, and a decrease of more than 15% could affect drinking water stations.

- An increase in the unemployment rate

  According to the WB, a high proportion of Egypt's economically active population is involved in agricultural activities (Kagwanja, 2007). An increase in the unemployment rate is expected to occur due to the expected reduction of the Egyptian cultivated lands, which eventually will affect Egyptians' welfare.

The FAO (2019) confirms that 30% of the Egyptians are directly working on farming activities, while another 25% are working in agriculture-related activities (agro-based industries sector). This is estimated to be about 55 million.

- Concerns related to the dam's collapse and the other aims behind it
  El Bedawy (2014) cautions that if the GERD were to collapse, approximately 18 km^2 of the Sudanese lands would be destroyed by flood before the rest of the massive flow reached Lake Nasser in Egypt. If the lake was full, there is a high chance that this flood could cause the collapse of the AHD. This would destroy most of the cities from the AHD in the south of Egypt all the way north to Cairo and the Delta.

  Abdulrahman (2019) alleges that the Ethiopian government is blocking information related to the GERD. The Ethiopian government's refusal to release information to the public, journalists, or researchers could lead Egypt to think that Ethiopia might need to use the water for purposes other than generating hydropower (e.g., irrigation, despite assertions to the contrary). This is much more disconcerting, especially with the latest Ethiopian and Sudanese proposals for building more dams along the Nile (Stanley & Clemente, 2017).

  Both downstream countries have different positions towards the GERD. These different positions are due to their different needs for water, different uses, different economic positions, and the different in-return benefits of the GERD for each of them. However, this study only focuses on Egypt's situation and the bilateral Egyptian-Ethiopian dispute.

2.3.6. The Egyptian-Ethiopian dispute over the GERD

The Ethiopian government announced its intention to construct the GERD in March 2011. One month later construction started on the dam, while Egypt was preoccupied with the revolution that began in January 2011 (Salman, 2016).

Both downstream countries, Egypt, and Sudan opposed the Ethiopian unilateral decision to build and fill the dam. The Egyptians fear the GERD will create major disruptions to their access to the Nile's waters. As a consequence of the objection, an international committee (the Nile Tripartite Committee - NTC) was formed in November 2011 to evaluate the GERD's effects on Egypt, Sudan, and Ethiopia. It consisted of 10 members: two representatives from each country and four international experts. The NTC issued its report signed by all 10 members in May 2013 (Salman, 2016). The report identified various problems with the analysis and documents presented by Ethiopia regarding the dam and criticised a lack of analysis by Ethiopia on several other critical issues. Furthermore, the report recommended conducting two comprehensive studies (International Rivers Org, 2013). The full findings and details of this report are discussed in Chapter 4. However, three days before the NTC published its report, Ethiopia diverted the Blue Nile to start constructing the dam, without approval from the two downstream countries (Salman, 2016).

After much deliberation, in March 2015, Egypt, Sudan and Ethiopia reached an understanding and signed the Agreement on the Declaration of Principles on the GERD (DoP) (International Water Law, 2015). This agreement obliged its three parties to undertake the two comprehensive studies recommended by the NTC, in addition to setting the guidelines and rules for the filling of the GERD and its annual operation thereafter. The current dispute started immediately after signing with arguments over the details and terms of reference for the studies (Salman, 2016).

Negotiations continued until 2019, with tensions flaring up between the parties. Article No. 10 of the DoP states that mediation could be used in case of the three countries fail to reach an agreement regarding the filling and operation of the GERD. The United States of America (USA) mediated talks between Ethiopia and the two downstream countries, Egypt, and Sudan. The three countries agreed to four rounds of talks, but Ethiopia withdrew from the fourth round, after rejecting the final draft of the proposed agreement (Egypt Today, 2020). In May 2020, Egypt submitted a petition to the UN Security Council (UNSC) asking Ethiopia to resume talks. The UN Secretary-General urged the three countries to continue with the negotiations (UN, 2020). In June 2020, the President of the Republic of South Africa, and the Chairperson of the African Union (AU) convened a new mediation, which led to resumed negotiations in a series of meetings between the three countries. Importantly, the three countries agreed to stop filling the GERD's reservoir until reaching a trilateral agreement (TCA Regional News, 2020), as will be explained in detail in Chapter 4. *However, one of the main points of disagreement during these negotiations relates to the filling time and the operation of the GERD in the dry seasons, especially in the absence of any explicit position to be taken by Ethiopia in relation to either matter.*

However, on 21 June 2020, the Ethiopian Prime Minister's office announced that the GERD's reservoir had been filled with the amount of water 'required for the first year', without first gaining approval from the two other countries (France 24, 2020). Ethiopia explained that the filling was justified given the need for a small amount of water to test the GERD's first two turbines (France 24, 2020).

Ethiopia undertook a second filling at the end of May 2021. The justification this time was to store enough water to install and operate the first two turbines of the dam again (Endeshaw, 2021). The explanation came after the Ethiopians first denied starting the second filling of the dam, despite Sudan claiming to have evidence that Ethiopia had resumed the filling process. Sudan's technical data records a decrease in the Blue Nile's level, meaning water was being pooled upstream (Alamin & Marks, 2021). On 5 July, the Egyptian irrigation minister reported Ethiopia's official notice of the commencement of the second filling phase, resulting in Egypt and Sudan voicing their objection and warning against further pooling without an agreement. Egypt further considered Ethiopia's unilateral action as a threat to regional stability (Atallah et al., 2021). The Ethiopian Minister for Water, Irrigation and Energy tweeted on 19 July that Ethiopia had hit the second-year target for filling the GERD (Endeshaw, 2021). Then Ethiopia undertook a third filling in August 2022 (Vincenot, 2022).

A diplomatic campaign by Egypt and Sudan for a legally binding agreement over the dam's operation led to members of the League of Arab States calling for UNSC intervention over the GERD (Atallah et al., 2021). At the UNSC-convened in-person briefing on 8 July (UN, 2021), the Sudanese Minister for Foreign Affairs asserted that the dam should be operated based on a trilateral legally binding agreement that considers equitable and reasonable utilisation without causing harm to the downstream States. She expressed concerns about threats posed by the dam's location close to the Sudanese borders where in the absence of tripartite cooperation it threatens half of Sudan and all of Egypt. She noted that Ethiopia refused all recent proposals to address the matter.

The Egyptian Minister for Foreign Affairs claimed that Ethiopia's unilateral actions are "Essentially declaring ownership of the Nile", and in breach of international laws. He asked the members to adopt Tunisia's draft resolution proposing an equitable agreement within a defined timeline. The Ethiopian Minister for Water, Irrigation and Energy objected to raising this issue to the UN Security Council, arguing that the other two countries have constructed different kinds of dams and canals without regard for other basin States' rights. He warned, "Ethiopia does not respond well to undue political pressure and interference". He rejected UNSC intervention. However, he announced that Ethiopia would continue the negotiations under the auspices of the AU. He also shared his belief that an agreement could still be reached between the three countries. He added, "None of us ought to stand thirsty while watching the others drink" (UN, 2021). At the time of writing, negotiations and talks over the GERD are still taking place intermittently, with significant tension in the air. The basis of Egypt's objections lies in the enormous impacts that the dam is expected to have on the country as will be explained in the next section.

2.3.7. The characteristics of the GERD case study

Whittington et al. (2014) illustrate that the GERD's storage capacity is huge in comparison with the Nile's annual flow. The Ethiopian dam reservoir can hold more than 74 bcm of water (Pietrangeli et al., 2017). However, the GERD will not hold 74 bcm of water immediately; it would need some time to accumulate this water. Meanwhile, Egypt will suffer from short-term and long-term impacts and risks because of the GERD (Whittington et al., 2014). The examination of the consequences associated with the GERD on Egypt (section 2.3.5) indicates that the characteristics of these expected risks can be divided into short-term and long-term impacts.

The short-term impacts are the expected impacts because of the GERD during the filling time of its reservoir. During this time, water to fill the dam will be taken directly from the Nile's flow, which will reduce the amount of water reaching Egypt. This reduced volume will be greater, the shorter the filling time (in a number of years). After the dam's reservoir is filled, smaller extractions will occur annually as the dam is kept full. However, further losses will occur as the stored water will suffer from evaporation losses. As the surface area of the reservoir increases, the evaporation losses will increase, and it is expected to reach 3 bcm per year, which according to El-Nashar and Elyamany (2018) will represent about a 5.9% increase in current evaporation rates. Hence, the operation of the GERD will have negative long-term impacts on the quantity and quality of the Nile's water and raise the water's salinity, because of the expected increase in the evaporation rates. This long-term impact on the environment could also impact the species living in AHD. These are all considered long-term effects.

Whittington et al. (2014) analyse other factors that could exacerbate this situation, such as a sequence of drought years; increasing the irrigation activities of the upstream countries that could further lower the Nile's flow; or uncoordinated filling operation time of the GERD without synchronising with the level of the Nile's flow. In addition, according to the Intergovernmental Panel on Climate Change (2007), changes to the climate are expected to have great consequences on the Nile. One of these consequences will be higher temperatures, which means higher evaporation rates than currently experienced.

2.4. Prior studies on the risks associated with the construction and operation of the GERD on Egypt

The above challenges regarding the Egyptian-Ethiopian situation have led researchers to several important discussions. Some of these adopted a historical perspective (Carroll, 1999; Okoth-Owiro, 2004; Ferede & Abebe, 2014); some were based on legal points of view (Salman, 2007; Abebe, 2014); some presented political points of view (Browing & McDonald 2013; Abdulrahman, 2019); while others take a risk perspective (Mulat & Moges, 2014; El-Nashar & Elyamany, 2018). All these discussions were built through one-dimensional analyses, using one perspective, or a maximum of two at a time.

Some scholars discussed the treaties regarding the Egyptian-Ethiopian situation by adopting a historical perspective. Abdo (2004) discussed the Anglo-Italian Protocol as the first treaty in history regarding the Nile, which included Article III, No. (136). The treaty was signed on 15 April 1891 between Britain, on behalf of Egypt and Sudan, and Italy, representing Eritrea. Swain (1997) discussed the Anglo-Congolese Treaty and the Tripartite Treaty (Anglo-Italian-French), both in 1906, while Okoth-Owiro (2004) discussed the Anglo-Italian Secret Treaty in 1925.

The Anglo-Egyptian Treaty in 1929 and supplementary agreements of this Anglo-Egyptian Treaty have been discussed, such as the supplementary agreement in 1932 (Wassara, 2014), the Anglo-Belgian Agreement in 1934 (Kidd et al., 2014), the Lake Tana agreement (Degefu, 2003), the Tripartite agreement (Anglo-Irish-Egyptian Agreement) in 1950 (Kasimbazi, 2010), and the last Nile treaty within the colonial era, which was the Owen Falls Agreement (Okoth-Owiro, 2004).

Interpretations of history represented in treaties have always played a significant role in disputes between countries. It is important to fully understand the past, which leads to a better evaluation of the current situation. However, it is not enough to only work on the past without taking into consideration other factors that could offer different views. All the previously mentioned studies and scholars have studied some of these treaties. Some of the strengths of their studies were in the quality of their presentation, and they explained the two countries' points of view regarding these treaties. However, their weakness lay in adopting the historical perspective as a one-dimensional perspective by which to judge the situation, which led to developing their opinions dependent only on this perspective. These views were very limited, which prevented them from capturing the big picture of this complex situation. Another weakness was that most of these studies did not explain the effect of the full list of treaties relating to the two countries; on the contrary, they only presented some of these treaties and accordingly offered a limited view.

Another perspective that scholars have used to study the conflict is the legal perspective. Many rules control the security and uses of transboundary water bodies. These rules are set by intergovernmental agreements, which were instituted depending on international law (Giordano et al., 2014; Demin, 2015). There are different sets of international rules regarding the navigational and non-navigational uses of international watercourses. Navigational uses of international watercourses were of more significance, which led to the first rules at the beginning of the 19th century (Salman, 2007).

Some scholars adopted the legal perspective to study the Egyptian-Ethiopian dispute. Some of these previous studies' strengths stem from the importance of shedding light on the legal view of the conflict by clarifying the legality or illegality of the actions, conditions, or intent. They showed the current situation according to the legal points of view. However, the weakness is that the legal perspective in studying the situation would not be enough to reveal the problem's complexity and ambiguity. The problem is too complicated to be studied from one perspective.

Simulation is used to show the impact of the GERD on Egypt and indicates that the Egyptian water share would be decreased (Sadek, 2012); the irrigation pumping stations along the Nile in Egypt will be affected (Ismail, 2013); the reduced water amount would influence Egypt's social-economic projects and cause damage in drinking pump stations (Sadek, 2013); the hydropower generation from AHD will be impacted, if the GERD's reservoir were to be filled in less than six years (Mulat & Moges, 2014); and the other negative risks on Egypt, if the reservoir filling time is less than six years (Ramadan et al., 2015).

These studies were the basic background estimates for this research. However, they are not enough to gain a better understanding of the whole situation; for example, they did not identify or question the root causes of the situation or explore different ways of managing the situation other than exploring different scenarios. These studies were by their very nature only focused on the quantitative aspects, which prevented them from capturing the complexity of the overall situation.

From the above clarification, it is apparent that the analytical approaches used in previous studies of the dispute have been limited in number. Other analytical approaches and tools such as risk and decision analysis and TOC have been overlooked. These approaches will provide different and useful perspectives on the situation.

2.5. Research gap

As mentioned earlier, in previous studies, many researchers have discussed the risks regarding the Egyptian situation due to the construction of the GERD. However, most of these discussions were one-dimensional analyses and depended only on one or two perspectives at maximum, which led to limited and single-track assessments of this conflict. The weakness of these studies derived from not considering many other aspects and many other impacts that could affect the situation and outcomes.

There is a paucity of published evidence and concrete examples of the application of risk analysis, except for using the simulation, and decision-making techniques, while a complete absence of the application of TOC. Additionally, there is no evidence of the use of a multi-framing approach to study the risks to Egypt's water supply due to the GERD.

The gap in prior analyses results largely from adopting a one-dimensional view of the Egyptian-Ethiopian conflict. The nature of the situation itself is so critical and complex, that using a one-dimensional view prevents an adequate understanding of the situation and its root causes, and limits the options open to consideration and therefore any solutions that may be presented. Indeed, the Egyptian-Ethiopian dispute could be described as a "wicked problem". Rittel and Webber (1973) describe wicked problems as undefinable, complex, and with an unclear mission. These problems include nearly all public policy issues. As such, when problems are inherently ill-defined and/or difficult to formulate in an acceptable manner, there can be no expectations of a defined analytical solution, as might be the case for well-defined mathematical or engineering problems, or for example, chess. Rittel and Webber's view of what constitutes a "wicked problem" is consistent with what was stated by Ackoff (1997). Ackoff (1997) characterises complex problems as "messes". He states, "Every problem interacts with other problems and is, therefore, part of a set of interrelated problems, a system of problems. Furthermore, solutions to most problems produce other problems. I choose to call such a system a mess". He explains that these messes are complicated because the problem definition depends on the solution, the stakeholders have radically different world views and different frames for understanding the problem, the constraints that the problem is subject to and the resources needed to solve it change over time, and the problem is never solved definitively. That is why it is important to adopt multi-dimensional views when studying this dispute.

Falkenmark (1990) and Doran (2009) both agree that especially water issues are critical and multi-faceted. These issues were oversimplified by scholars to make them easy to analyse, which led to short-sighted and insufficient approaches to dealing with water security. The research gap not only relates to the application of practical knowledge but also to the methodologies employed. It reflects multiple shortcomings associated with single-lens or single-frame approaches and suggests a potential benefit from a multi-framing approach.

The importance of this research stems from studying the risks of the GERD's construction on Egypt from different perspectives, which leads to a better understanding. Moreover, it will address the implications of the GERD on Egypt's agricultural sector, and whether these consequences can be identified, controlled, alleviated, and evaluated. This leads to the establishment of practical solutions that could be applicable.

2.6. Research questions

The main question of this research is "What are the expected risks to Egypt's water supply due to the construction and operation of the GERD in general and the consequent disruption to Egypt's water supply and impacts on the agricultural sector in particular, and how can Egypt deal with these risks?" Moreover, the case analysis provides an example of how to approach disputes over shared watercourses.

The study intends to address identified research gaps by answering the main question and sub-questions of the research, which are:

1) What is the nature of this situation (from each of the chosen perspectives)?
2) What are the relationships, challenges, and risks for the agricultural sector related to water supply shortages in Egypt due to the GERD construction?
3) What are the root causes of the conflict (between Egypt and Ethiopia)?
4) What are the root causes of the agricultural sector problems before the expected impacts due to the GERD?
5) How can the consequences of this situation be identified, controlled, alleviated, and evaluated?
6) How a better understanding of the uncertain nature of the current situation could be gained to provide different stakeholders and decision makers with deep insights that can support their decision-making process?
7) What are the current and expected implications for Egypt due to this situation?
8) What are the suggestions for possible alternatives that when implemented could help to overcome these risks and lead to practical solutions for decision makers and stakeholders?

The research answers these questions by using the proposed multi-framing approach. It adopts multi-level, multi-framing perspectives and approaches to develop a better understanding of the Egyptian-Ethiopian conflict and problems associated with the Egyptian agricultural sector, gain deep insights, and propose alternative actions. This will be done to provide different stakeholders and decision makers with a platform for understanding the sector to support their decision making and potentially improve the sector's outcomes.

Various analytical frames have been chosen within the multi-framing approach. These include historical, legal, PIM, decision trees and tables frames, and TOC frames as will be explained in detail in the next chapter.

2.7. Summary

This chapter has reviewed the background and literature review of this research. It starts with the importance of the Nile to ancient Egypt. It is followed by the Nile's geographical background. Then, it shed light on the prior studies of the risks associated with the GERD on Egypt, which clarifies the research gaps and questions related to studying the current situation. The chapter concluded by outlining a multi-framing approach adopting different perspectives that will be used to explore this complex situation as it affects Egypt. The next chapter explains the methodologies used to address the issue of how to manage the risks to Egypt's water supply due to the GERD including the proposed perspectives and the multi-framing approach.

Chapter 3
Research Methodology

3.1. Introduction

This chapter explains the research paradigm, research design, and the four different perspectives that will be used in this multi-framing study. Moreover, it discusses the research's different approaches and the expected benefits of each. This is followed by a detailed description of the data collection procedures and data analysis approach.

3.2. Research paradigm

It is essential to illustrate the philosophical assumptions that underpin any research. Philosophical assumptions usually refer to three kinds of beliefs. First is the "ontology", which is the nature of reality or worldview the researcher adopts. Second is the "epistemology", which is the nature of that knowledge and how it could be developed. The third is the "methodology", which is the methods used in the process of research (Creswell, 2007). In the context of this study, the critical realism (CR) perspective is adopted by the researcher.

CR is considered a valuable philosophical framework for many disciplines. It gained popularity over the last few decades (Fletcher, 2017). CR was revealed in the 1970s and 1980s in Bhaskar's work to provide a middle reasonable ground among different philosophical frameworks (Fletcher, 2017).

Bhaskar (1986) believes that the world's greatest minds cannot realise all things surrounding humans. According to CR, to understand the real world we not only need to observe the events, but we must observe and also analyse the relationship between causes and effects to impose meaning. This meaning gives rise to fully understanding a situation and the appropriate solutions. CR also encourages the use of multiple perspectives to catch sight of the whole picture as well as to recognise the complexity of reality. Moreover, the use of CR is recommended as a philosophical view that underpins the systems-managerial based studies for more engagement with practical problems (Mingers, 2004).

Choosing an appropriate philosophy for research depends on the nature of the research itself, its best implications, and the research world of view. The methodology of this study conforms with the principles of CR because it analyses the situation using different perspectives, that is, a multi-framing approach, seeking cause-effect relationships among others. Moreover, this study's approach is compatible with CR in that it challenges the assumptions about cause-effect relationships and the existence of entities by using logic protocols, particularly those drawn from the domains of TOC and decision-making frames. In addition, it seems that a CR paradigm is appropriate for this study when taking into consideration the complexity, system-wide effects and characteristics of the Egyptian situation that necessitate the use of CR.

3.3. Research design

This study is a mixed method approach and is exploratory in nature, while it uses a sequential strategy to apply such a combination. The mixed method approach is an approach combining two or more methods, which may be quantitative, qualitative, or a mix of both. The strategies of this combining could be sequential, concurrent on different levels, or transformative (Creswell, 2014). The sequential strategy for mixing methods is when the researcher expands the findings of one method based on the understanding of the previous method(s). It is when each method builds on the groundwork and insights of the previous one (Creswell, 2014).

The mixing approach was introduced first by Campbell and Fiske in 1959 when they studied the validity of psychological traits by using multiple methods. This encouraged others to mix different approaches, which later led to the combining of approaches associated with both qualitative and quantitative data. This was proven later to be efficient as the results or insights from one method can help develop or inform the other method or insights derived from that method. This combination creates more recognition of the research problem than using each one of them separately (Creswell, 2014). This method suits when using a case study as an instrument (Zachariadis, Scott, & Barrett, 2010).

In the context of this study, some frames use a quantitative approach, such as the PIM frame and decision trees and tables frames, while some other frames, such as the TOC, use a qualitative approach. The method of this combining is sequential. It starts with two qualitative analytical frames, the historical and legal frames. Then, it is followed with quantitative analytical frames, PIM frame and decision trees and tables frames. It ends with a suite of TOC qualitative frames.

Yin (1984) claims that an exploratory case study is a popular tool in research. Zainal (2007) agreed and added that one of the main features of a case study is that it allows exploration and perceives the intended meaning of complex issues.

Yin (2015) defines the case study as an empirical examination that closely investigates a contemporary phenomenon within its actual-world context. The case study as an approach reinforces an in-depth investigation of any phenomenon. Eisenhardt and Graebner (2007) observe that the case study is often used in management research. Both Easton (2010) and Yin (2015) confirm that using a case study allows the researcher to offer insight into the nature of the studied phenomenon and can lead to significant outcomes.

Easton (2010) declares that the case study as a research tool is "well suited as a companion" to CR when the study is exclusively involved with the deep thoughtful research process to conclude, "Why things are as they are". This thesis uses the case study as an instrument for gaining knowledge and to understand the complexity of the Egyptian situation; identify the root causes; evaluate the risks; understand how to control, alleviate, and evaluate them, to suggest integrated risk analysis frameworks to ameliorate the situation.

3.3.1. Single case study with one embedded unit of analysis

Yin (2015) explains two types of case studies. One could be a single-case study, while the other could consist of a multiple-case study. It is based on the nature of the study itself to choose which type should be adopted. Gustafsson (2017) explains that the multiple-case study fits with various experiments, or compares differences and similarities among cases, or compares different outcomes, while Siggelkow (2007) claims that the single case study allows a researcher to be singularly focused on a phenomenon.

The determination of the case study boundary or unit(s) of analysis is required for better practice when using a case study as an instrument for research (Baxter & Jack, 2008). Yin (2013) categorises case studies with different units of analysis into four main categories, which are a single case with a single unit of analysis; a single case with multiple units of analysis; multiple cases with a single unit of analysis; and multiple cases with multiple units of analysis.

In this study, the approach of a single-case study is adopted to allow for total focus on the details and the consequences of the GERD and foster a deep analysis of the Egyptian-Ethiopian dispute over the Nile. This study adopts a single unit of analysis associated to this single case, according to the categorisation that was made by Yin (2013). This thesis focuses only on the Egyptian agricultural sector as the unit of analysis for this case study, as will be explained in the next section.

This situation would have different consequences in many sectors. However, this study focuses on one sector, agriculture, for two reasons, as will be explained in the next section.

3.3.2. The focus of the case study – Agriculture

While the GERD will affect many sectors, this thesis focuses on one sector, agriculture, as the unit of analysis for two reasons. Firstly, it is the most affected sector because of the expected reduction in Egyptian cultivatable lands. Secondly, choosing one sector will allow this study to research these risks in greater depth. The risks associated with the agricultural sector especially are explained in the next section.

Egypt has always seen itself as an agricultural nation (Abdelsalam et al., 2014; Abdulrahman 2019). Agricultural activities consume the majority (about 70%) of the Egyptian share of the Nile's water, which is the country's only considerable source of water. Kagwanja (2007) reports that about 96% of the Egyptian population is living on the Nile's banks on a thin strip of land, while 86% of total Egyptian land is classified as very arid. Egypt depends entirely on the Nile as the main source of fresh water and irrigation required for growing crops to feed its people. Vast areas of land are irrigated by the Nile to grow different crops, vegetables, and fruit. Whittington et al. (2014) demonstrate that Egypt might not be capable of supplying enough water to meet its agricultural needs because of the GERD construction.

El Bedawy (2014) asserts that Egypt is already facing a water scarcity crisis. The situation grows rapidly worse each year with population growth preventing Egypt from achieving self-sufficiency of food. Consequently, Egypt imports more than 50% of its demand for cereals. Different irrigation projects have been constructed by Egypt along the Nile, such as the Isna Barrage, Nag Hammadi Barrage, and Asyut Barrage. These Barrages will be impacted by the reduction of the Nile's water flowing from Aswan.

Abdulrahman (2019) states that the reduction of cultivated lands is one of the major side effects expected to happen because of the water decrease. A reduction of 1 bcm of water would cause the loss of 200,000 acres of cultivated lands and affect the livelihoods of 1 million people. Many farmers in Egypt are worried about the future of their lands. El-Nashar and Elyamany (2018) report that a loss of 29.47% of Upper Egypt agricultural lands and 23.03% of Delta lands are expected to happen because of the GERD.

Other activities such as the agro-based industry will also be affected by the expected damage to the agricultural sector. The Food and Agriculture Organisation of the United Nations (FAO) (1997) defines the agro-based industry as “the subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector, including forestry and fisheries”. Two categories likely to be affected are: industries processing agricultural commodities, such as rice and flour milling, cotton ginning, and fish canning; and manufacturing operations using agricultural crops as production inputs, such as bread, textiles, paper production, and clothing manufacturing (FAO 1997).

El-Enbaby et al. (2016) state that in a country like Egypt with a long tradition of farming, agricultural activities are significant providers of jobs in agriculture, agro-industry, and agro-service sectors. In 2006, the WB reports that more than 90% of the Egyptian economically active population was working in agricultural and agriculturally related activities. These activities consume about 70% of the Egyptian share of the Nile’s water (Abdelsalam, Aziz, & Agrama, 2014) and 88% of the total amount of the Egyptian water from all different resources, despite contributing only 14% of Egyptian Gross Domestic Product (GDP). Agricultural expenditures are 17% of Egypt’s fiscal budget. Egyptian irrigation subsidies reach US$5 billion annually (Shetty, 2006). These figures have been decreasing over time. However, these activities are still characterised as highly labour-intensive.

The FAO (2019) confirms that the livelihood of 55% of Egyptians depends on the agricultural sector in one way or another; in which over than 30% of this figure is directly working on farming activities, while the other 25% is agriculturally related (agro-based industries sector). An increase in the unemployment rate is expected due to the losses of Egyptian agricultural lands. Thus, the Egyptian per capita income and income distribution would be affected due to the increase in the unemployment rate, which eventually would affect Egyptian welfare and lifestyle.

For the above reasons, it is obvious that the agricultural sector is one of the most affected sectors and hence it was chosen as the unit of analysis for this case study.

3.4. The perspectives of complexity and multi-framing approach and reasons behind choosing them in this study

Multi-framing is the process of investigating and viewing the same problem by using different frames to cover different perspectives to reveal the problem’s ambiguity and achieve a better managerial understanding (Bolman & Deal, 1991; Mabin & Davies, 2004; Tengblad, 2012). Davies and Mabin (2001b) state that in the 1980s and 1990s, the concepts and methodology of framing have gained acceptance and credibility to study complex systems.

The complexity of a system could be characterised as the state of having many different parts and facets connected or related to each other in a variety of direct, indirect, and time-related ways. These different facets make it difficult to understand or find an answer to a problem related to this system. “A complex system is one whose evolution is very sensitive to initial conditions or to small perturbations, one in which the number of independent interacting components is large, or one in which there are multiple pathways by which the system can evolve" (Ladyman et al., 2013).

The use of multiple perspectives and analytical frameworks helps to effectively manage complexity to provide deeper insights into the problem context. Framing enhances the ability to understand the surrounding problems. It uses many perspectives to improve perception and gain an accurate and deep intuitive consciousness of the real situation. Davies and Mabin (2001a) explain that framing has different advantages. One of these advantages is that it acts as an umbrella that can gather many different methodologies beneath it. Another advantage is that it allows the modeller to use different methods to shed light on aspects that may have been shadowed by previous frames. Using a multi-framing approach will enable more effective actions to be designed (Bolman & Deal, 1991; Mabin & Davies, 2004; Tengblad, 2012), offering a broader range of solutions to solve the problem (Mabin & Davies, 2004).

Mabin and Davies (2004) state that most real problems are complex, with many details, and different aspects, which need to be examined using different modelling approaches, as no one method can hope to model all aspects of a complex situation. In other words, the multi-framing approach is the best fit for complicated situations in that a single frame is inadequate to reveal due to vagueness and uncertainties (Davies & Mabin, 2001b). Multi-framing is therefore highly appropriate for this study, especially with the accompanying characteristics of the current conflict.

Many scholars ascribe "multi-methodologies" to the same definition of "multi-frames" (Bolman & Deal, 1991; Mingers & Brocklesby, 1997). Mingers and Brocklesby (1997) debate that choosing the methodologies and frameworks to be combined must rely on the user's "skills, knowledge, personal style and experience at a particular point in time". They argue that people cannot be expected to bring into play frames, methods, and techniques that they are not familiar with, or that are not compatible with their styles. Moreover, a multi-framing approach requires that users must realise the study's context, explain the nature of the frameworks used, and determine how these frames could together complementarily interpret complex problems (Davies & Mabin, 2001b).

In this study, perspective is a particular way or view that represents a specific dimension, while the frame is the tool or method used to study or represent this perspective. For example, in this study, the risk perspective is a particular way of considering/representing the risk dimension. The PIM, decision tables and trees are the frames/methods/tools used to study this perspective.

This study benefits from using a multi-framing approach to analyse the impact of the GERD on Egypt. Four perspectives (historical, legal, risk, and TOC) are used to develop views and provide different interpretations of this situation. Each perspective can use single or multiple frames and examine it at different levels (local or international) to provide an in-depth system view and range of potential solutions. This study acknowledges the role of the case context through the choice of its frames. For example, selecting a historical perspective is important to fully understand the impact of the past in a bilateral dispute between two countries over a shared watercourse.

Frame selection considered the theoretical and practical goals of the research, the researcher's background and experiences, and the problem itself.

Moreover, some of these frames have not been used before to study this issue. This is the first time that the TOC, TPs and 5FS tools have been used to work on the Egyptian-Ethiopian dispute or even the agricultural sector in Egypt in general. It is considered the first time that TOC has been used in an international water dispute between two countries. The suite of TOC frames used will help in revealing the complexity of the situation and facilitate the provision of providing different solutions.

The next section discusses different frames used in the multi-framing analysis to explain how they work, the tools they use and the reasons behind choosing them.

3.4.1. Historical perspective

History, in the broadest sense, can be defined as a course of events taking place over time, while this course is limited by human deeds, actions, and events (Rotenstreich, 1987). Rotenstreich (1987) states that history's interpretation should consider "both the overall process which involves human beings in their entirety, and also the impact which the total process has, or may have, on the course of events as they affect human beings".

Historiography was first described in the 5th century BC by Herodotus who is known as the "Father of history" (Evans, 2014). Historical analysis is an important activity to learn about the past, which mainly relies on recalling important facts and data from the past to promote reasoned judgments about important human matters (Drie & Boxtel, 2008).

Historical reasoning is widely used as an analytical historical approach. It is an approach that requires the analysis of history not only through the knowledge of the past but also by using this knowledge for the interpretation of past and present events. This approach provides a good use of historical evidence to fully explain historical events. Moreover, it describes well the historical changes or any other interrelated activities (Drie & Boxtel, 2008).

Historical analysis should also recognise the full worth of the historical context in which defining different aspects, such as a time, place, or event, are important to study. Moreover, the term "contextualisation" in historical analysis means to organise data about the past to constitute a pattern. This pattern could describe, compare, and/or explain a historical event or phenomenon. The application of various skills and social knowledge is required to interpret historical events while taking into consideration their historical context and their interrelation at the time of the studied event (Drie & Boxtel, 2008).

Three different techniques can be used to contextualise historical events, which are: chronological order analysis, spatial analysis, and social analysis. A chronological order analysis defines periods, important events, and their development, in chronological order. A spatial analysis acknowledges the locations and scale of events, while a social analysis defines knowledge of human behaviour and social activity. The first technique, chronological analysis, is considered one of the most significant techniques in analysing historical events. This approach provides deep insight into how we can understand historical times and events. Additionally, it puts these events in chronological order (Drie & Boxtel, 2008).

3.4.1.1. Reasons for choosing the historical analysis frame

Historical contextualisation is a significant perspective that directly influences the causes, reasons and methods used to judge any theory's elements through a certain context (George & Jones, 2000). Additionally, historical analysis can reveal data that would improve our understanding, reasoning and judgement about significant human matters and events. At the same time, this analysis takes into consideration the role of the historical context. Other factors are also considered, such as the understanding of the causes of historical events and their significance, the outcomes, and how the past affects the present (Drie & Boxtel, 2008).

Over the last two centuries, many treaties and agreements on the Nile were concluded. Some of these treaties have given rise to the current dispute due to the different interpretations of them by each country.

The historical analysis provides a narrative describing the events and treaties chronologically, which is again analysed to provide deep insights and the views of all parties to describe the current situation. The historical analysis is a descriptive analysis that is not intended to yield a solution, but without it, the whole analysis would be flawed and baseless, as it examines the historical evidence and treaties to present the views of all parties to better understand the past, which can, in turn, lead to better evaluation of the current situation and help in resolving the problem in the future. However, this frame neither studies the current situation nor suggests how to resolve the situation nor foreshadows the future. Hence the need to include other analytical frames.

3.4.2. Legal perspective

A dispute can be defined as a controversy over the facts. Two parties do not agree on what exactly happened, who said or did what, or what laws are applied to the dispute, the laws' interpretations, and their way of application. This legal dispute could be brought for resolution through any of the legal dispute resolution methods (negotiation, mediation, arbitration) (Statsky, 2015).

During disputes, facts are information that describes the events. Legal rules could include legal international rules, enforceable governmental standards of conduct, constitutions, treaties, statutes, charters, and relevant case law. The application of these suitable legal rules and principles to the facts of a studied case is a legal analysis (Statsky, 2015).

The IRAC framework is the most widely-used method for legal analysis. IRAC stands for Issue, Rule, Analysis, and Conclusion. This framework first defines the Issue and determines the suitable applied legal Rules. It allows for analysis of the issue by applying these rules to deduce a Conclusion (Miller & Charles, 2009). This framework is best suited to analysing case studies, where a legal dispute is first identified based on the given facts and then analysed to reach a conclusion related to this case or dispute (Bittner, 1990).

International water law was developed to create a framework of generally accepted rules under which countries can opt to mutually engage in managing water resources and avoid or settle disputes. However, there is no denying that many water disputes have been solved or softened by diplomatic means. Meanwhile, cooperation may prove itself a keyword for the endeavours of countries that aim to preserve peace and stability and build a comprehensive framework for development and enduring human progress (Kittikhoun & Schmeier, 2020).

The most important three rules regarding the security and uses of transboundary water bodies are Helsinki Rules (HRs) (1966), the United Nation's Convention on the Law of Non-Navigational Uses of International Watercourses (UNC) (1997), and Berlin Rules (BRs) on Water Resources (2004) (Salman, 2007).

3.4.2.1. Reasons for choosing the legal analysis frame

Rotenstreich (1987) claims that studying the laws that control a historical event overcomes the fragmentary nature of historical awareness. This provides wider contexts or a protection against fragmentation. This was one of the reasons that led the researcher to choose this frame next, as it builds on the first historical analytical frame.

Spain (2009) claims that using international laws is one of the preferred ways for resolving conflicts if the parties have agreed to be bound by them. He believes that an international legal perspective could address different criteria by offering a descriptive framework to analyse the legality or illegality of a state's behaviour.

The IRAC framework is widely used to evaluate and analyse legal situations in disputes, with a particular focus on the results of case study analysis (Bittner, 1990). The critical thinking aspect of the framework is important in the application of the IRAC on disputed issues of different case studies (Miller & Charles, 2009).

This frame addresses the current situation based on the legal points of view. It reveals the legal view of the conflict between Egypt and Ethiopia over Nile water, by clarifying the legality or illegality of the actions, conditions, or intent according to different international transboundary water laws relating to the conflict.

In the context of this study, the dispute itself (Issue) was explained before in Chapter 2. The legal analytical frame provides a literature review, which studies the Egyptian-Ethiopian dispute over the Nile against the background of international water law principles and relevant legal cases (Rules). It first determines and summarises the relevant international water law, and analyses their principles to clarify the legality or illegality of actions, conditions, or intent of both countries (Analysis). Then relevant case law is used to show how international laws have been applied to similar disputes (Analysis). This analysis leads to a conclusion end about the legal situation of both parties (Conclusion).

However, this frame does not assist with analysing past and future situations. Additionally, it does not suggest any solutions. Hence the need for using other analytical frames.

3.4.3. Risk perspective

There is no “just right” definition of risk. Definitions of risk and uncertainty have been the subject of controversial debates and disagreements between academics, experts, decision makers and other stakeholders. Therefore, there is no single generally accepted definition of risk. Defining risks mainly depends on the perception adopted to study these risks, such as scientific, informal conceptions, or personal judgments (Boholm, Möller, & Hansson, 2016).

Veland and Aven (2013) assert that consciousness and knowledge of various risk perspectives help in solving problems. Many scholars and institutes hold the view that studying the perspective of risks is crucial for the success of any system, Emblemsvg and Kjlstad (2006); Project Management Institute (PMI) (2017); Aven and Flag, (2018). That is why it matters to identify and study these risks through risk analysis.

Emblemsvg and Kjlstad (2006) explain that the need for risk analysis stems from the rapid changes taking place in our world. These changes must be considered in light of their own unique variable risk factors. Moreover, risk analysis makes it possible for decision makers to reason more effectively or defend choices to take or ignore risk. There are various reasons to use the PIM frame. The first is to provide insights regarding the studied risks. The second is to define the threats and opportunities of any event. The third is to help in assessing the probabilities and impacts of these threats and opportunities. The fourth is to rank these risks based on these assessed probabilities and impacts, which later would help in prioritising those risks (Aven & Flag, 2018).

Risk analysis requires personal experience, knowledge, and creativity, which are relative and subjective in most cases (Emblemsvg & Kjlstad, 2006). On the one hand, some scholars have criticised the use of subjective knowledge in this framing of risk, as will be explained in the next section. However, in this study, the multi-framing approach offers several perspectives to overcome this problem by using multiple frames to reveal the problem’s ambiguity and achieve a better managerial understanding (Bolman & Deal, 1991; Mabin & Davies, 2004; Tengblad, 2012).

On the other hand, Lanfranchi et al. (2015) explain that relative and subjective personal experience is significant to risk analysis. It ensures the involvement of different stakeholders in the overall risk analysis process. Stakeholders could be the source of information that provide different kinds of knowledge for good risk evaluation. Moreover, their participation would ensure the acceptance and support of future decisions, in addition, to being more willing to adapt to change. Lanfranchi et al. (2015) define stakeholders as individuals or groups who are influenced or can influence by the achievement of certain objectives. It is a party with an interest, whatever this interest is. Stakeholders could also be risk bearers, whether they are forced to take risks or simply bear the consequences. That is why it was important to involve stakeholders in the evaluation of the risks to Egypt’s water supply in this study. As will be explained later in the data collection section.

In this study, the risk perspective was developed through three different frameworks, which are the Probability Impact Matrix (PIM), decision trees and decision tables frames.

3.4.3.1. The key concepts of the PIM

Many scholars have used this tool, such as Dumbravă and Iacob, 2013; Lanfranchi et al., 2015. Dumbravă and Iacob (2013) posit that the PIM is one of the most widely adopted tools for risk analysis and evaluation, with outcomes presented in descriptive terms.

The PMI (2017) defines this matrix as a grid for mapping the likelihood and severity of positive and negative risks. The matrix takes into consideration the probability (likelihood) and impact of a certain event by assigning scores to both. These scores will be assigned for each category of the identified risks. Then, these two scores will be multiplied together to classify these risks according to the importance, priority, and categories of each risk (Dumbravă & Iacob, 2013). Thus, the risk is a combination of multiple factors, rather than a single factor. The overall results of combining these factors differ in each case (Lanfranchi et al., 2015).

Ouabouch and Amri (2013) illustrate that the PIM is also useful to visualise the hierarchy of risks. It evaluates risk and allocates its overall score on the matrix itself, which makes it much easier to visually compare different evaluations for the same event or risk. Dumbravă and Iacob (2013) affirm that risk calculation is very simple using the PIM. However, the range and number of levels accepted for risk probability and impact are mainly related to the context of the risk or event itself. More levels mean more detailed risk analysis. Descriptive terms or numeric values are used to evaluate different risks (PMI, 2017).

Dumbravă and Iacob (2013) divide the probability and impact into different categories depending on the evaluation of their scores. This tool enables the evaluation of threats, and opportunities, by presenting different interpretations for the definition of impacts. Risk probabilities are often divided into five categories: very likely (almost certain), likely, possible, unlikely, and very unlikely (rare). The impact is also divided into five different categories: very high (catastrophic), high, moderate (medium), low, and very low (insignificant).

The PMI (2017) assigns numeric values to the matrix as shown in Figure 2. The numeric values of the probability of occurrence, namely 10, 30, 50, 70, and 90%, relate to the descriptive terms of very unlikely (rare), unlikely, possible, likely, and very likely (almost certain) respectively. The numeric values of the impact of 5, 10, 20, 40, and 80% are equivalent to the descriptive terms of very low (insignificant), low, medium, high, and very high (catastrophic) respectively. The multiplication of both scores generates a new number called the risk score. The risk scores are allocated to the three coloured areas shown in Figure 2, reflecting a low, medium, or high risk taking into consideration the two factors.

Probability	Threats Risk score = Probability x Impact					Opportunities Risk score = Probability x Impact				
0.90 Very likely	0.05 Low	0.09 Medium	0.18 High	0.36 High	0.72 High	0.72 High	0.36 High	0.18 High	0.09 Medium	0.05 Low
0.70 Likely	0.04 Low	0.07 Medium	0.14 Medium	0.28 High	0.56 High	0.56 High	0.28 High	0.14 Medium	0.07 Medium	0.04 Low
0.50 Possible	0.03 Low	0.05 Low	0.10 Medium	0.20 High	0.40 High	0.40 High	0.20 High	0.10 Medium	0.05 Low	0.03 Low
0.30 Unlikely	0.02 Low	0.03 Low	0.06 Medium	0.12 Medium	0.24 High	0.24 High	0.12 Medium	0.06 Medium	0.03 Low	0.02 Low
0.10 Very unlikely	0.01 Low	0.01 Low	0.02 Low	0.04 Low	0.08 Medium	0.08 Medium	0.04 Low	0.02 Low	0.01 Low	0.01 Low
Impact	0.05 Very low (Insignificant)	0.10 Low	0.20 Moderate (Medium)	0.40 High	0.80 Very high (Catastrophic)	0.80 Very high (Catastrophic)	0.40 High	0.20 Moderate (Medium)	0.10 Low	0.05 Very low (Insignificant)

Figure 2: The PIM (PMI, 2017, p. 408).

In this study, the PIM is used to identify the probabilities and severity of risks due to the GERD on Egypt's water supply based on the evaluations of international experts to classify and prioritise these risks to know how bad the problem is.

3.4.3.2. Reasons for choosing the PIM to study the GERD case

There are arguments for and against this tool. Cox (2008) acknowledges that the PIM is one of the most popular tools used in different fields, such as construction project management, terrorism risk analysis, climate change risk management, as well as in national and international standards (e.g., Military Standard 882C and AS/NZS 4360:1999), and by many other organisations and risk consultants. However, Cox claims that risk matrices have flaws that could call into question their performance. Firstly, these matrices are not always able to compare different pairs of risks, which leads eventually to poor resolution for these hazards. Secondly, the inaccuracy of risk matrices could lead to higher qualitative ratings of quantitatively low risks than is justified. Thirdly, they cannot be depended on to allocate resources effectively. Fourthly, it involves the user's subjective interpretation to evaluate its likelihood and severity. Thus, careful judgments and caution must be taken when using risk matrices. Likewise, Peace (2017) concludes that risk matrices, when designed insufficiently or used inefficiently, would increase the negative effects of the situation. He suggests that to counteract their shortcomings, risk matrices should not be the only tool used to evaluate risks.

Talbot (2011) rebuts Cox's (2008) criticisms. Talbot argues that risk matrices could be useful in providing consistency in prioritising risks, enhancing strong discussions, keeping decision makers more focused on top-priority risks, and reporting complicated risks in a simple way. However, Talbot agrees with Cox's (2008) four points and adds two further points. First, risk matrices cannot be used in assessing risks in different timeframes, e.g., the impact of risks because of an incident in the short term is different from its evaluation in the long term. Second, they sometimes simplify the risk's complexity.

Talbot states that no other tool allows for the comparison of different pairs of risks, but the same ratings for different quantitative risks can be assigned in risk matrices. It is not the risk matrices' role to allocate different resources or to provide mathematically precise data. It is the responsibility of the risk manager to adopt the right risk interpretations and treatments. Moreover, he indicates that these matrices are one of the most widespread, practical, and convenient tools that will always be attractive for use. The nature of decision making under uncertainty by humans with different perceptions is one of the risks involved in the risk assessment process regardless of the tool being used. Additionally, these matrices are not responsible for making decisions; they only support risk-informed decisions. He points out that these flaws could only occur when these matrices are used as a single tool to assess risks, which is rarely the case.

Talbot's view is supported by Dumbravă and Iacob (2013). They affirm that the risk matrices have the same characteristics as many other tools that are used for the qualitative assessment of risks. There are many reasons for using a risk matrix as a qualitative risk approach. First, it is more easily understood by any of the decision makers, or people who are not experts in using sophisticated tools. Second, it can be quickly applied to draw a clear perception of any studied risk. Third, it does not need a quantitative evaluation or special program to apply it. Fourth, it does not require qualified staff or difficult training. Fifth, the volume of data required to carry out this evaluation depends on the user. Sixth, sometimes it identifies new undiscovered aspects of the studied risks. Seventh, it is easily explained to third parties.

Thus, based on the arguments above, this tool has been chosen as the first risk analysis framework for this study to rank the main three characteristics of the expected risks to Egypt's water supply. These three characteristics are: the probability of occurrence (likelihood), its impact (effect or severity), and its criticality. The criticality is determined by multiplying the other two characteristics to classify these risks. Moreover, it evaluates the importance and priority of each risk, classifying risks into different categories, based on the matrix. This tool thus highlights how serious the problem is to Egypt due to the GERD. However, this frame does not help to solve the problem or discuss its root causes. The tool's flaws were mitigated by using other frames and tools, for risk assessment and more broadly when studying the case.

3.4.3.3. Decision analysis frames

Howard (1988) writes that decision analysis has a foundation and has been deeply rooted for centuries in philosophical values based on uncertainties and decision-making concepts. Decision analysis is also significantly useful to human beings.

Howard (1988) claims that what Laplace wrote in 1812 could represent an optimistic view of what decision analysis is today. This journey started in the early 1700s when Bernoulli wrote his famous paper in Latin entitled: "Specimen theoriae novae de mensura sortis", which formed mathematical equations reflecting different attitudes toward risk. Later, this paper was translated into English with the title "Exposition of a new theory on the measurement of risk." In 1763 Bayes suggested that probability had epistemological power that surpassed its random uses. In the modern era, this field started with statistical decision theory and is still in progress. All these mentioned contributions led directly to decision analysis. The importance of decision analysis is that it replaces confusion with clear insight, which leads to determining a desired course of action. It reveals vagueness and opaque decision problems. Opaque means “hard to understand, solve, or explain; not simple, clear, or lucid.”

Howard (1988) defines a good decision as an action that is made intentionally and mindfully while including all relevant factors such as the individual’s preferences, philosophy, perceived alternatives, information, and values. Decision analysis differentiates between decisions and consequences by explaining the whole process of decision making, hence improving the quality of these decisions.

Decision analysis helps in creating different and new alternatives for the decision. Moreover, decision analysis concepts ensure the analysis of decision problems effectively (Howard, 1988) and explore situations which could be beyond people’s existing experiences (Girling, 2013). The importance of using the Decision Analysis frame in this study is to explore the known aspects of the heated Egyptian-Ethiopian current dispute, which could be beyond individuals’ existing experiences while taking into consideration different outcomes that might not yet have happened. This eventually helps in creating decision alternatives and exploring new paths for the future, to develop long-term strategic plans based on the nature of the conflict.

Decision making can be divided into two categories. Decision making under conditions of risk assumes that the probabilities of each event can be evaluated (Khan, 2017). Decision making under conditions of uncertainty assumes that the probabilities of each event are unknown (Khan, 2017). In this study, decision trees and payoff tables were used to organise data collected through interviews. Decision trees were analysed using the Expected Value criterion (EV) while decision tables used five other different criteria to analyse the data. Both categories and tools will be explained in the next sections. The next flowchart summarises these tools and approaches.

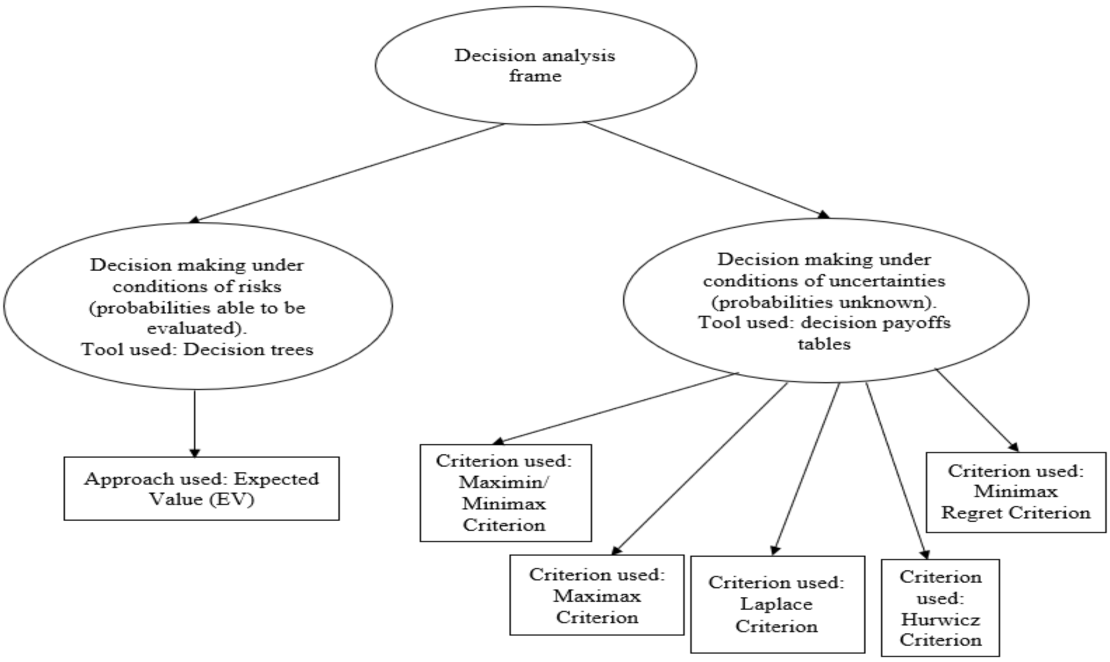


Figure 3: Flowchart shows the type of conditions, tools, and criteria used in this frame.

3.4.3.3.1. Decision making under conditions of risk (DMUCR)

Magee (1964) states that decision trees are used especially in assessing more complex questions or situations involving different players or firms. These situations could include decisions that occur in stages, or over time. The decision tree analysis is usually used to make a decision based on multi-stage processes in a reactive phase while examining different strategic behaviours to compare them. Moreover, it is more suitable in situations involving more risks. It helps in comparing competing alternatives for any decision by calculating numerical values for each of these alternatives (Olivas, 2007). This analysis suits complicated decisions, which need more graphical representations to show the routes of these decisions (Magee, 1964).

The decision tree is used to graphically portray different decision alternatives. It is a visual representation in the shape of a tree. This tree consists of nodes and connecting branches. There are three types of nodes. A small square node represents the root node or decision node, which indicates the first set of decision alternatives or represents a firm decision. The circle node represents a chance node, which results in two or more outcomes. Each outcome has its own probability of occurrence. This relative probability for each outcome is evaluated by experts. Endpoints (terminal points), represented as small triangular nodes, come at the end of each branch. These endpoints express that there is no more information to be represented. For branches, each represents one decision alternative or an outcome from this node. The branch can end by any of the three types of nodes (Magee, 1964).

For the EV criterion, it is usually used to evaluate the relative merits of each decision alternative. This criterion is commonly well-established and accepted. EV is the weighted value of a decision's payoff under its expected probabilities. For each decision alternative, EV could be defined as the mathematical combination of the "payoffs for each course of action times the probabilities associated with each state of nature". It can be expressed as:

$$EV\ (X_i) = \Sigma X_i P_j = X_1 P_1 + X_2 P_2 + ... + X_i P_m$$

Where $EV(X_i)$ is the EV of the variable X for the *i*th course of action, and P is the probability corresponding to each state of nature j (for i = 1, 2, 3, …, n and j = l, 2, 3, …, m; and $i \neq j$). The decision with the higher EV for each chance node is considered better, in comparison with other alternatives (Khan, 2017).

3.4.3.3.2. Decision making under conditions of uncertainty (DMUCU)

In the real world, the probabilities of each outcome are not always known, even if the outcomes of the decision can be evaluated with some evidence. Our real world is nondeterministic in nature, where uncertainty is a key factor. For a decision-making process under conditions of uncertainty, the decision alternatives (courses of action) must be determined, and the possible outcomes (the states of nature) and payoffs resulting under each state of nature must be estimated. States of nature are uncontrolled conditions that the decision maker cannot influence (Khan, 2017).

Decision tables are used to graphically represent decision alternatives and their expected outcomes. This table is also known as a decision matrix or payoff tables. Yuan and Chen (2013) claim that the decision matrix is one of the most popular tools to deal with multiple decision alternatives, whose outcomes are future events, while Kasimbeyli (2007) describes decision tables as showing the various kind of actions, which are available to decision makers. Payoff tables are best used when there are different decision alternatives and/or if the outcome is a function of a future event. In these tables, rows represent the alternatives of any possible decision, while the columns represent any possible future event. The payoffs are to be entered in the tables.

Various criteria have been developed to analyse and evaluate the data in these payoff tables to take the right decision (choose the best alternative course of action) (Khan, 2017). In this study, five criteria are used to analyse the data. These criteria are Maximin criterion, Maximax criterion, Hurwicz's criterion, Laplace's insufficient reason criterion, and Savage's Minimax regret criterion.

- Maximin/Minimax criterion
  Abraham Wald took the credit for introducing this criterion. It is usually used by risk-averse or conservative decision makers. It is based on the worst possible case or scenario. This criterion offers two facets, Maximin criterion and Minimax criterion. Firstly, the Maximin criterion is used to select the decision that maximises the minimum possible payoff. It starts by addressing the minimum payoffs for all decisions. Then, the decision with the maximum "minimum payoff" is chosen. The Maximin criterion is best used with gains to choose the maximum gain from the minimum possible gains. Secondly, the Minimax criterion is better used with losses. It chooses the alternative with the minimum loss out of all the maximum possible (loss) outcomes (Khan, 2017).

- Maximax criterion
  By comparison, this criterion is based on the best possible case or scenario. Usually, it is used when decision makers are risk-seeking and looking for the best possible payoff. Here the decision maker chooses the alternative that will produce the maximum of the "maximum" payoffs (gains). In this approach, the maximum payoffs for all decisions are determined. Then the decision with the maximum "maximum payoff" is selected (Pažek & Rozman, 2009). This is for gains. The equivalent strategy for losses is "minimin", choosing the alternative with the minimum loss out of all the possible minimum loss outcomes.

  Both Maximin and Maximax decision criteria (and their loss counterparts Minimax and Minimin) are based on taking extreme views of possible outcomes when deciding between decision alternatives, which in the real world are not taken completely by decision makers. In real life, most decision makers are not totally optimistic or pessimistic all the time. They vary their attitude towards risk based on different circumstances and the situation (Khan, 2017).

- Hurwicz's criterion
  First introduced by Leonid Hurwicz in 1951, this criterion tries to find a middle ground between the Maximin and Maximax criteria. Hurcwicz allows any knowledge there is about the risk-bearing propensity of the decision maker to be considered - if they are neither perfectly risk-seeking nor risk-averse. As the extremes are most unlikely to be the case in practice, they can be useful for circumstances where probabilities are not known but where the risk-bearing propensity is. It first identifies the maximum and minimum payoff to each action and then assigns a weight for each of them (Pažek & Rozman, 2009). This weight is called the coefficient of optimism, given by α, which is used to show a degree of compromise between optimistic and pessimistic views. This coefficient ranges between 0 and 1, where 0 reflects total pessimism, while 1 reflects total optimism (Khan, 2017). It is also called the coefficient of realism. The determination of the value of α is subjective to the decision maker. Determining a value for α produces at the same time a value for the coefficient of pessimism (1 - α). The Hurwicz weighted average payoff (H) can be formulated as follows, where A_i is an action alternative (Pažek & Rozman, 2009):

  $H(A_i) = \alpha$ (row maximum) + $(1 - \alpha)$ (row minimum) - in the case of positive payoffs
  $H(A_i) = \alpha$ (row minimum) + $(1 - \alpha)$ (row maximum) - in the case of negative payoffs

- Laplace's criterion
  This criterion treats all probabilities equally. It assigns the same value for all probabilities of future states of nature. To put it another way, this criterion assumes that since all probabilities of future events are unknown, they could be assumed to be equally likely. The Principle of Insufficient Reason is the logic behind this assumption. This principle explains that if we are ignorant about the causes of things that happen in nature, it does not mean that there is no cause, even if it is trivial. Therefore, there is no reason to believe that a certain probability will occur preferentially compared to another (Khan, 2017). This principle was first introduced by Jakob Bernoulli in his book "Ars Conjectandi", Bernoulli's posthumous masterpiece, which Simon De Laplace later made use of in articulating this criterion. This criterion calculates the average payoff (over all possible outcomes) for each alternative and selects the alternative with the largest average payoff (Pažek & Rozman, 2009).

- Minimax regret criterion
  L. J. Savage developed this approach in 1951. Usually, it is used when decision makers are feeling pessimistic and conservative. This criterion seeks to minimise the regret felt for making the wrong decision. This may be desirable in policy contexts for risk-averse decision makers.

This approach depends on evaluating the "lost opportunity" or "regret" to minimise this regret. Opportunity loss is the difference between one decision's outcome and the outcome of another alternative that would have led to better results or gains. First, determine the best payoff for each outcome. Then, the regret value for an alternative decision is calculated as the difference between its payoff value under a given state of nature, and this best payoff value among all decision alternatives when this state of nature occurs. We then choose the decision alternative which yields the best regret value for each decision. The optimal decision in this approach will be for the alternative that has the minimum of these "maximum regrets" (Pažek & Rozman, 2009). This criterion is based on comparing alternative actions with the alternative that produces the largest possible payoff if this alternative is assumed to be attained (Khan, 2017). It is the criterion that reflects a decision that would be made with perfect hindsight.

3.4.3.3.3. Reasons for choosing DMUCR and DMUCU tools and criteria

- Decision making under conditions of risk (DMUCR)

A decision tree is usually used to make a decision based on a multi-stage process while exploring different strategic behaviours to compare them. It is suitable in situations involving more risk. It compares decision alternatives by calculating numerical values for each of these alternatives (Olivas, 2007). This analysis fits better in complicated decisions, which need more graphical representations that show the routes of these decisions (Magee, 1964).

Furthermore, decision trees are useful to help make decisions, especially under conditions of risks. Different reasons support choosing the decision trees for this purpose. First, the decision alternatives, payoffs, and assigned probabilities are graphically represented in a simple way. Second, this representation helps in understanding the sequence of the decisions and dependencies of the outcomes (Olivas, 2007). Third, a decision tree is better than tables in more complicated decisions that are more easily represented as a diagram. It displays a lot of data more clearly than a table (Magee, 1964). Fourth, a decision tree is efficient. It could be easily updated when have more information or when the situation changes. Fifth, it is used to compare different decision alternatives in different states of nature. Sixth, it could be used in conjunction with other approaches as a complementary approach (Olivas, 2007).

The EV is a very popular and easy criterion to use when making decisions under risk, i.e., where probabilities are assumed to be known. EV weights each of the predicted payoffs by their assigned probabilities to create one single numerical value. This value allows the user to reveal and compare the merits of the competing decisions (Khan, 2017), which makes it easier for the decision maker to decide. In addition, the calculations of the EV are considered simple (Olivas, 2007).

However, decision trees and EV often depend on very subjective evaluations. Additionally, EV is based on a long-term probability distribution so is best suited to a decision that is repeated multiple times. The studied case is a one-off decision due to the nature of the conflict itself. Moreover, the decision trees frame does not provide a solution for the conflict, which could be considered a weak point.

In the context of this study, on the one hand, the purpose of using decision trees is to analyse decisions that are based on multi-stage processes. These trees show the actions that could be taken by the two players, Egypt, and Ethiopia when adopting a certain strategic behaviour. They also clarify the availability of different options in a reactive phase for both parties, while considering the probabilities of each outcome. Decision trees as well as EV contribute when making decisions under conditions of risk. Moreover, EV is used to create one single value based on the weight of its predicted payoffs by their assigned probabilities for each decision alternative. This value reveals and compares the merits of the competing decisions.

On the other hand, decision trees and EV do have flaws such as subjective evaluations and one-off decision. It is envisaged that these flaws can be mitigated by using other frames to complement the results of the decision analysis. In addition to decision trees, decision tables using five different criteria, are also used to assess different scenarios to make decisions under uncertainty, which will in turn provide insight related to decision alternatives. Referring to the inability of decision trees to provide a solution for the conflict, the TOC tools will address this deficiency.

➢ Decision making under conditions of uncertainty (DMUCU)

Five different criteria are used to analyse the data assessed by these tables. Each criterion is suitable for a different type of decision maker or different situations they face, among risk-averse decision makers, risk-seeking decision makers, decision makers that search for a middle ground, or even decision makers who are afraid of losing opportunities or feel regret. However, decision makers vary in their attitude towards risk based on different circumstances and the situation at hand (Khan, 2017).

Using different criteria offers more perspectives, which gives the opportunity to work on the decision of this case study because of its nature as an international dispute. These criteria show the results in case of pessimism, optimism, a compromise between both decisions, equal probabilities, and value of the lost opportunities and regret associated with each decision alternative.

There are several reasons to use decision tables. These tables deal with problematic situations, whenever the probabilities of the decision alternative outcomes are unknown (Khan, 2017). In this study, decision tables are used to assess different scenarios from a proactive point of view. In other words, these tables are used in a single stage to present the four decision alternatives from one player's view, Egypt, whose outcomes will depend on the different states of nature and actions adopted by Ethiopia, as explained in Chapter 6.

The purpose of using these tables would be to eliminate the weak decisions in favour of decisions that would be more beneficial to Egypt. However, it could be argued that decision tables are better used in decisions that are not difficult to present, in the case of few decision alternatives and few possible outcomes (Magee, 1964). Another potential weakness is ignoring the probabilities of the outcomes because they cannot be known precisely, and in the extreme, assuming that all outcomes are equi-probable. Furthermore, in real situations, decision making could be based on a sequence of dependent decisions.

Therefore, decision tables contribute to making decisions under conditions of uncertainty, while its flaws are mitigated by using the previous criterion, EV, which considered the probabilities of each outcome to make decisions under conditions of risks based on multi-stage processes.

However, this decision-making framework does not provide a solution for the conflict nor assist in identifying the root causes and undesirable effects of the problems. Therefore, a detailed and rigorous analysis using the TOC is used in this study to complement the former frames, resulting in several proposed solutions for this critical situation.

3.4.4. Theory of Constraints (TOC) perspective

Watson et al. (2007) assert that the TOC is one of the methodologies that could improve systems in different fields. These fields could include project management (Leach, 1999; Umble & Umble, 2000; Steyn, 2001); supply chain management (Rahman, 2002; Simatupang et al., 2004); retailing (Gardiner, 1993; Goldratt, 1994); process improvement (Schragenheim & Ronen, 1991; Gattiker & Boyd, 1999); production environments (Koziol, 1988; Raban & Nagel, 1991) and elsewhere.

In practice, the TOC methodologies have been adopted by multinational companies, not-for-profit organizations and government agencies such as: 3M, Amazon, Boeing, Delta Airlines, Ford Motor Company, General Electric, General Motors, Lucent Technologies, Habitat for Humanity, Pretoria Academic Hospital, British National Health Service, United Nations, NASA, and the United States Department of Defence (Watson et al., 2007).

The diversity offered by the TOC's different tools helps in problem diagnosing and solving, solutions development and implementation (Davies et al., 2005). These tools include the TOC 5FS along with a group of thinking tools known as the Thinking Processes (TP), which cover the processes of logic-tree mapping and conflict resolution (Dettmer, 2007).

Mabin and Balderstone (2003) reviewed the early literature, especially the 5FS and confirmed that the TOC is widely accepted and has led to considerable improvements in lead time, cycle time, and profits based on a meta-analysis of over 80 successful applications of the TOC, where companies reported quantified impacts of using the TOC. Kim et al. (2008) reviewed the literature on the TOC TP in the public domain, documenting the TOC's development and applications between 1994 and 2006. They stated that the TOC's (5FS) and TPs provide a

systematic approach to solve complex problems through efficiency and effectiveness. Reid (2007), Kohli and Gupta (2010), and Robbins (2011) used the TOC's (5FS) to improve different kinds of processes. Reid applied the TOC to a service process in a bank, Kohli and Gupta, to a throughput process, while Robbins' application was to a social goods delivery process in the public sector.
The TOC TPs help in better understanding any situation. They explain causal relationships, which eventually lead to creating solutions for various problems. Rahman (2002) used these tools to qualitatively analyse supply chains by identifying their undesirable effects (UDEs) and critical success factors (CSFs). Then he determined the causal relationships for a better understanding of those factors. Taylor and Thomas (2008) use the TOC TPs to answer the TOC's three questions regarding the improvement of the invoicing process of a consulting firm. They determined "What to change", "What to change to", and "How to cause the change" to enhance this process. Four years later, Dalci and Kosan (2012) proved how effective those tools were in enhancing hospitality operations to improve customer satisfaction. In the same year, Lin et al. (2012) improved the process of the operational logistics processes within the national research institutions by applying the TOC TPs. It was slightly complicated because of the size and number of the operational processes.

This study combines the TOC TP analysis and the 5FS with other established qualitative and quantitative research methods in a complementary fashion. Thus, it aims to raise the academic rigour by forming a satisfactory and balanced use of different methodologies. Figure 4 summarises the flow of the TOC TPs.

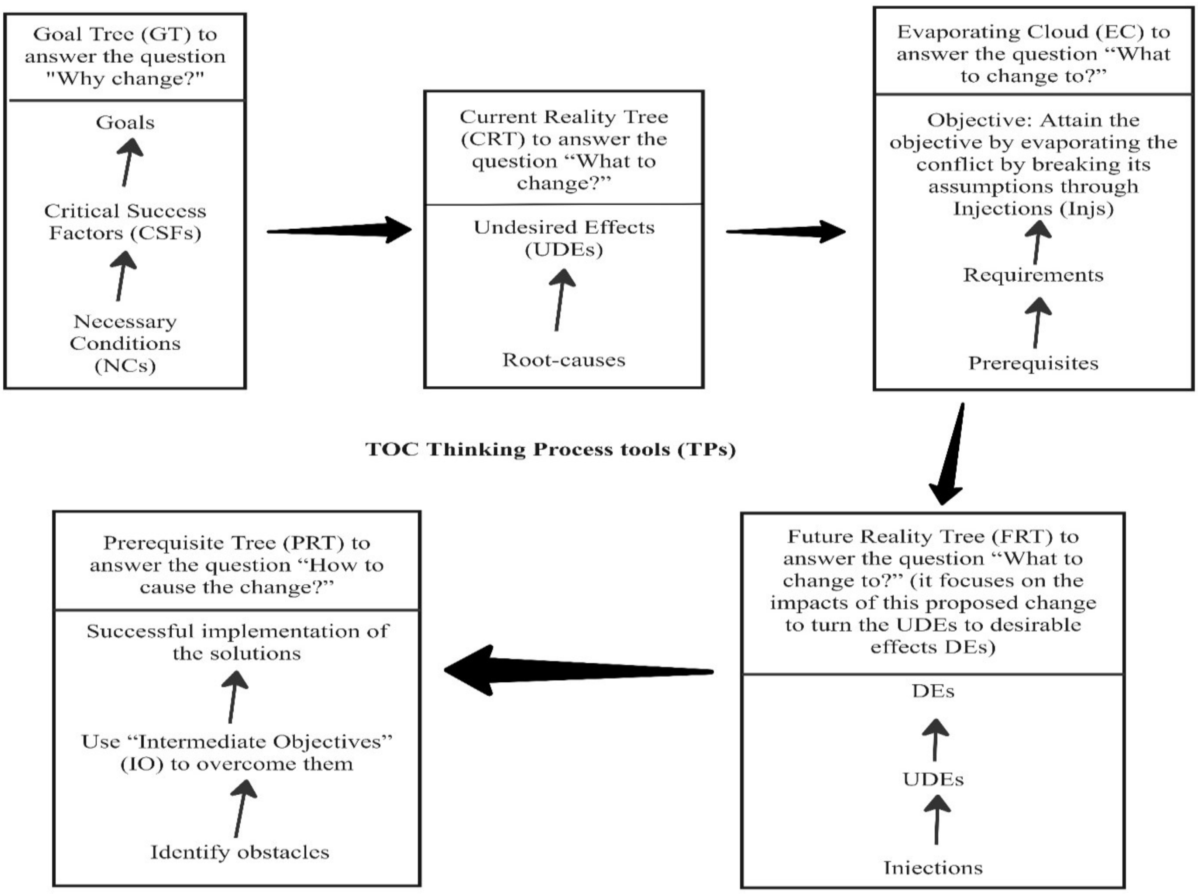


Figure 4: TOC TPs, Cox et al. (2003) and Dettmer (2007), reformatted by the researcher.

3.4.4.1. Goal Tree (GT)

The Goal Tree (GT) (Dettmer, 2011) starts with the premise that any system must have a goal. This goal is the ultimate purpose of this system. The critical success factors (CSFs) and necessary conditions (NCs) must be identified to achieve this goal. These conditions and factors are the standards that could measure the success or failure of any system. The GT locates the strategic goals at the top of the tree, with the CSFs below, and the NCs at the bottom to make it all possible to achieve these goals as shown in Figure 5. The GT is a "necessary condition" tree, addressing what is needed to achieve a goal, and in doing so, usually answers the first question "Why change?" by identifying the necessary conditions for success that are currently not being met (Dettmer, 2011).

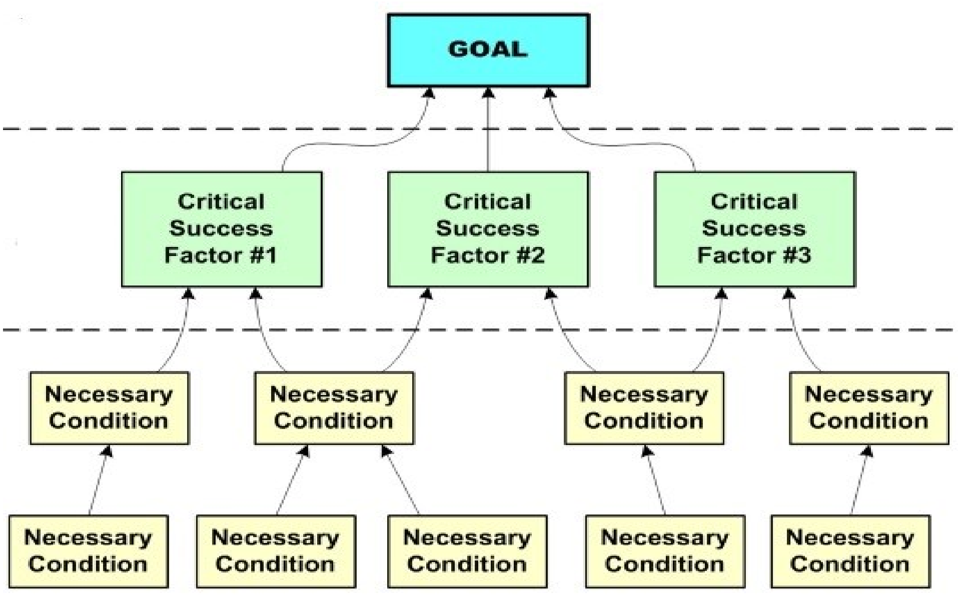


Figure 5: GT structure (Dettmer, 2011).

The GT is an important but lesser-known component of the TP. Dettmer, over 15 years, continued Goldratt's early work on the "Intermediate Objectives Map" (IOM), which he later called the GT (Dettmer, 2011).

In this study, a GT was created by using Dettmer's (2011) version of the model to show the desired goals to be accomplished to mitigate the risks to Egypt's water supply due to the GERD on the Egyptian agricultural sector. In addition, CSFs and NCs derived from the data are articulated, which helps in capturing the bigger picture.

However, the GT does not study neither the RCs of the situation nor the UDEs of these causes. Therefore, using the CRT is significantly important for this study.

3.4.4.2. Current Reality Tree (CRT)

When the CRT was introduced by Goldratt in the 1990s, before the development of the GT, it was the entry point into the Thinking Process, and answered the question, "What to change?". This was originally the first question in the Change questions sequence but is now the 2nd question.

Dettmer (2007) explains that the CRT clarifies the undesired effects (UDEs) of a situation by analysing its current state and exploring the RCs of the key problems. The tree starts from the bottom with RCs and moves upward to the UDEs as shown in Figure 6. The UDEs are negative aspects of a current reality. They are undesirable to the goal of the system (Goldratt, 2010). The CRT uses sufficiency logic and is a "cause-and-effect" tree.

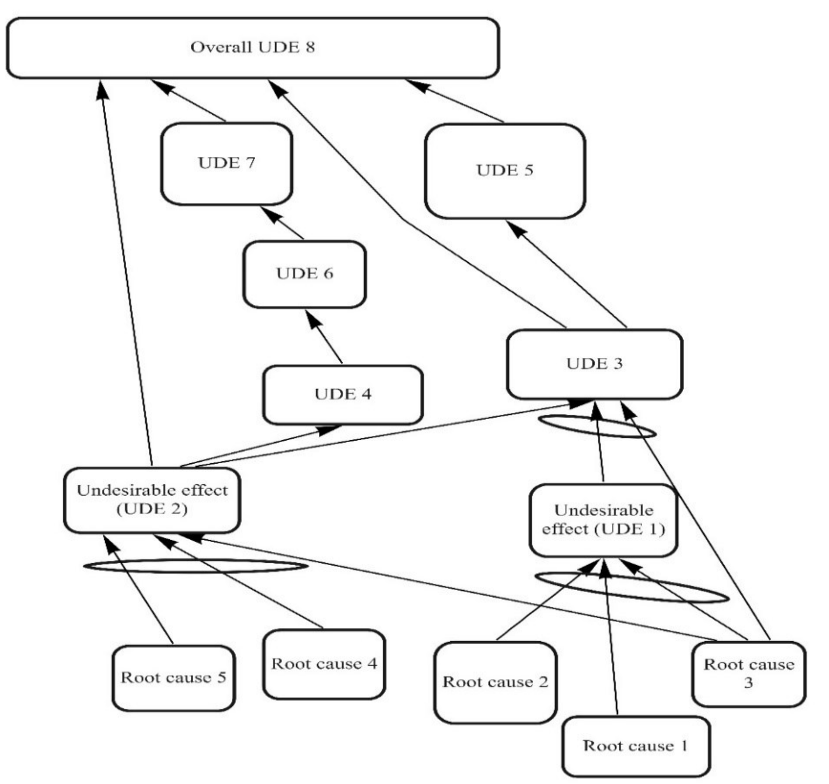


Figure 6: CRT.

In this study, the CRT's sufficiency logic (If .. then…) is used to identify the UDE's which represent the symptoms of Egypt's problematic situation, in order to trace down to the currently-hidden RCs of the situation. This will investigate how and why the risks to Egypt arise from the construction and operation of the GERD and its subsequent impacts on Egypt's water supply and the Egyptian agricultural sector.

However, the previous tools and approaches have not found any solutions for the situation yet. Here comes the role of the powerful tool, the Evaporating Cloud (EC). The EC assists by suggesting solutions, which are urgently required in such a heated situation.

3.4.4.3. Evaporating Cloud (EC)

Many times, decision makers face difficult situations when forced to decide between two conflicting decision options. The EC is a very powerful tool that helps to solve this conflict. It challenges the assumptions that underpin the assumed conflict to produce a resolution and evaporate clouds (Goldratt, 1990, 1994).

Watson et al. (2007) state that the EC depends on necessary condition logic. They concur that EC is specialised in the “do” stage by identifying a suitable solution. Kim et al. (2008) explain that EC generates solutions that start to answer the third question “What to change to?”. The most distinguishing characteristic of the EC is that it works when there is no acceptable compromise. It leads to a win-win solution by breaking the assumptions underlying the necessity links.

The EC diagram is seen in Figure 7. The diagram is built from right to left. However, it is read from left to right. EC has an imaginary line to depict two different points of view. The opposing views that represent the conflict or dilemma must be determined first (D, D'). Then the needs should be established (B, C). The logic must be checked by reading the EC from left to right by using “In order to ... we must ...”. Finally, the shared objective must be established (Fedurko, 2013). In other words, the top half of the EC represents one view (BD), while the lower half represents the opposite view (CD'). The assumptions of each side should be surfaced, and then challenged to evaporate the cloud and end the dilemma or conflict by breaking these assumptions. Injections represent the ideas that should be generated to solve the conflict and lead to a win-win solution (Cox et al., 2005).

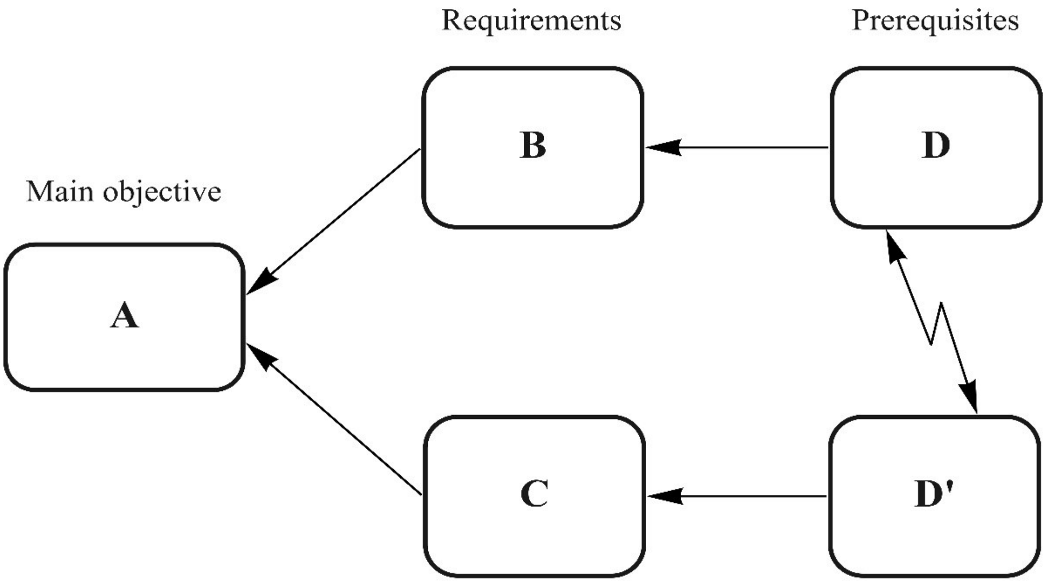


Figure 7: The EC (Cox et al., 2005).

Mabin et al. (2009) explain that there are two common approaches to evaporate the cloud, the methodical way, and the quick way. The methodical way is a 2-step process of identifying the assumptions and then breaking them into the proposed injections. The assumptions and injections should be provided for AB, BD, AC, CD', and DD'. The quick way works directly on ways to break the conflict by asking:
How can we get B and D' at the same time?
How can we get C and D at the same time?
And how can we have both D and D'?

Mabin et al (2009) state that the "quick way" could be efficiently used for generating breakthrough solutions. In the context of this study, due to the time and length constraints for a PhD, coupled with a large number of methodologies, analytical frames, and tools – especially the 13 ECs - used in this research, the researcher decided to use the quick way to resolve the clouds. Some key assumptions have been added in Appendix B for illustrative purposes.

After this clarification, it is obviously understood why using the EC is important in this case. As an international water dispute, this dispute has unique characteristics. The two countries are arguing over a shared watercourse, with no acceptable compromise allowing settlement of the conflict. Diplomatic ties are tense while the dispute remains unresolved and ready to flare up at any moment. This situation emphasises the need for expeditious creative solutions. In this study, the EC will be used to find solutions that could help the Egyptian decision makers to deal with this situation.

However, the proposed solutions in themselves are not enough. The EC alone cannot prove if these solutions would lead to a desirable future. There is a need to check if these solutions are going to work before the actions are implemented. That is the reason to use the FRT next.

3.4.4.4. Future Reality Tree (FRT)

Dettmer (2007) claims that the FRT uses sufficiency logic to construct a map showing the likely results of the proposed actions. These actions should lead to a desirable future. An FRT is built to check that this is the case before the actions are implemented. The FRT answers the third question "What to change to". It focuses on the impacts of this proposed change. FRT helps in creating solutions that, when implemented, mean that DEs take the place of the existing UDEs (Goldratt, 1994). The tree starts from the bottom with injections to RCs of different problems. These injections should turn all UDEs into DEs, while the tree is proceeding to move upward, as shown in Figure 8 (Dettmer, 2007).

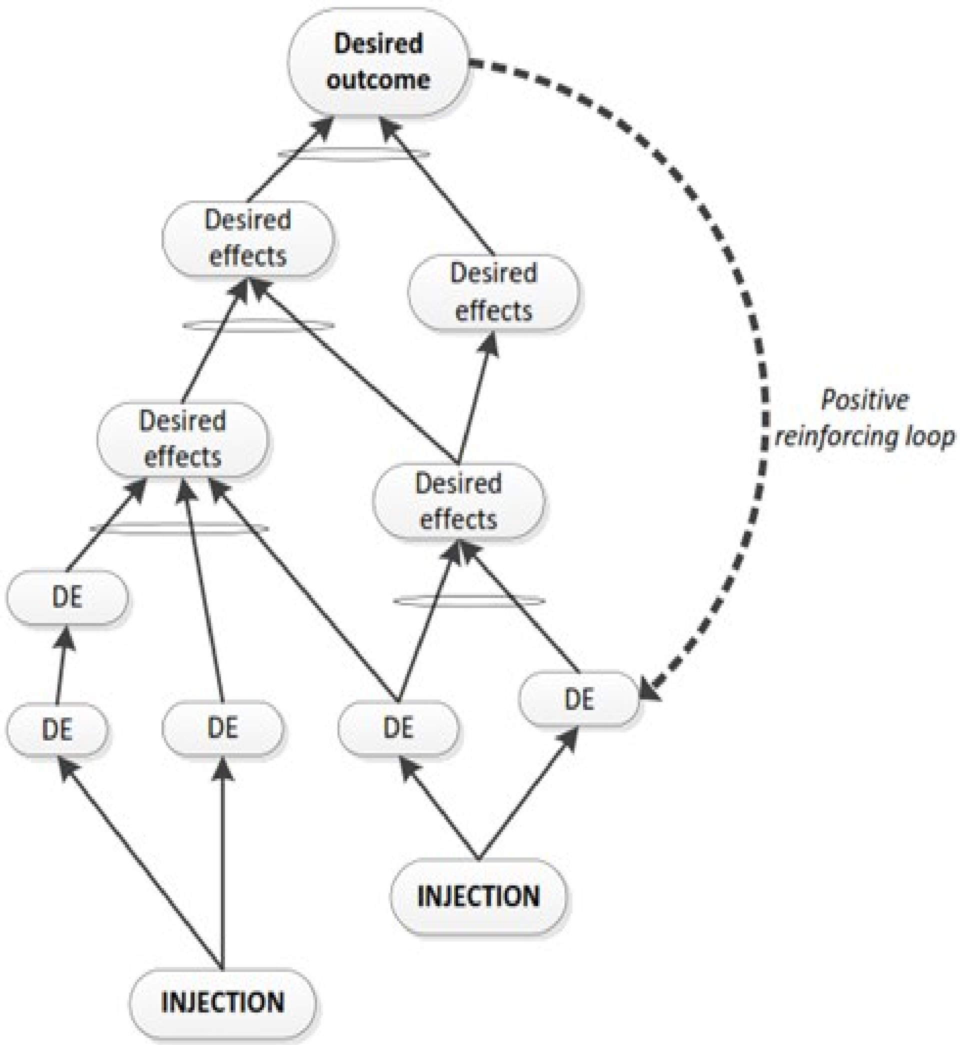


Figure 8: FRT (Dettmer, 2007).

There are different aims for using the FRT. It examines how effective the new ideas are before redirecting any of the resources (Mabin, 1999). In this study, the water resource is extremely limited, and people's lives depend on it. Mabin (1999) adds that the FRT predicts if the proposed changes lead to the desired effects with no collateral damage. In this study, the situation is extremely critical, so there is no tolerable margin of error, which makes the use of the FRT significant. Mabin (1999) argues that the FRT is a persuasive tool for decision makers in supporting a desired course of action.

This study seeks to inform decision makers with suitable solutions that might improve Egyptian performance toward the problems related to Egypt's water supply in general and to the agricultural sector in particular. Hence, that would improve alternative actions that can improve the sector's performance and effectively manage the agricultural and water practices, which eventually would lead to a desirable future. This is what makes the use of the FRT significant for this study and the reason behind its implementation.

However, the FRT cannot identify the obstacles that could prevent progress towards the implementation of the proposed solutions. Next, the PRT is used to identify these obstacles and the actions required to overcome them.

3.4.4.5. Prerequisite Tree (PRT)

Şimşit et al. (2014) indicate that the PRT is used to answer the fourth question "How to cause the change?". This question is concerned with how any system should implement the solution to achieve the change.

The PRT is a tool to identify obstacles (Obs) that could impede progress towards the implementation of the proposed solution. The PRT also shows what obstacles could hinder the process of solving a problem. The tree itself consists of two elements. First is the obstacles, and the second is the "Intermediate Objectives" (IO), as shown in Figure 9. The IOs are the actions required to be taken to overcome those obstacles, which help deal with conflicts and the resistance to change within any system (Davies & Mabin, 2009).

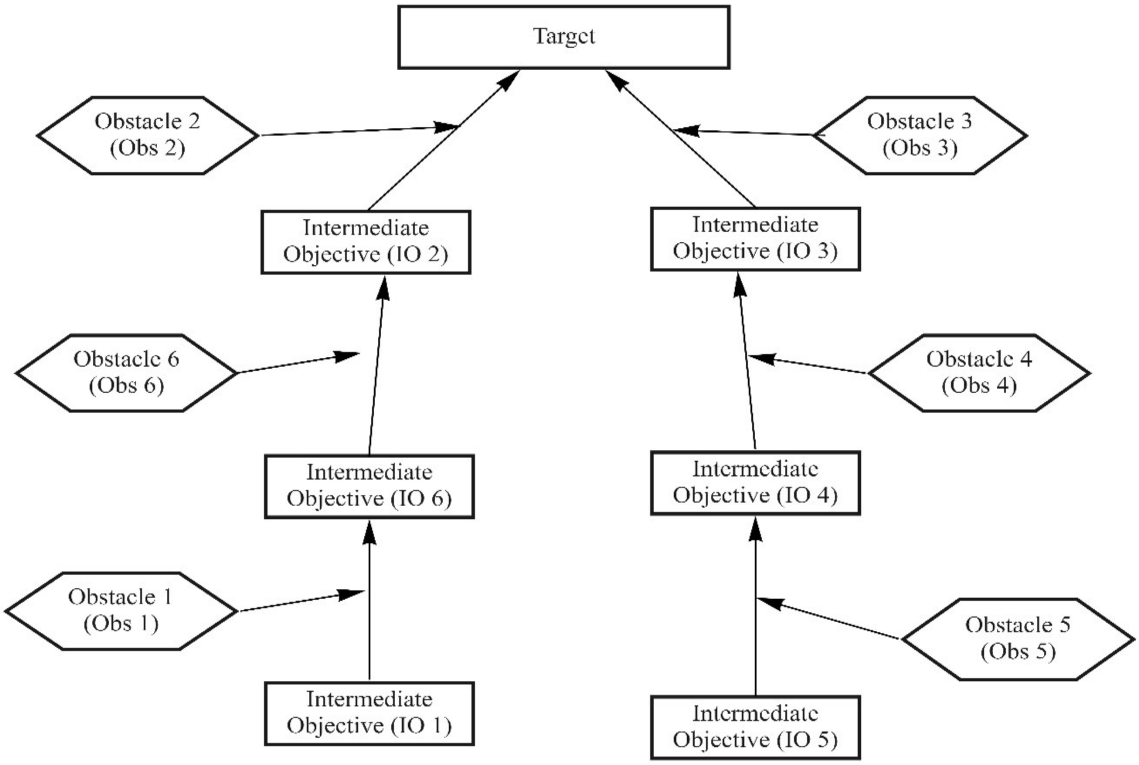


Figure 9: PRT (Dettmer, 2007).

PRT will be used to determine the obstacles and the required steps to deal with the risks to Egypt's water supply due to the GERD on the Egyptian agricultural sector. Moreover, obstacles and IOs identified from the data are articulated to answer the fourth question: "How to cause the change?" to help implement the solutions.

However, the 5 TPs previous tools do not identify the constraint that limits our system from achieving a higher level of performance. Next, the 5FS are used to identify and exploit this constraint and subordinate other activities accordingly.

3.4.4.6. TOC Five Focusing Steps (5FS)

TOC has always been used as a philosophy of continuous improvement and problem solving (Goldratt & Cox, 1984; Kim et al, 2008). The 5FS was first described in Goldratt and Cox's novel "The Goal" (Goldratt & Cox, 1984). The novel has subsequently seen many revised editions. Figure 10 summarises how Goldratt's 5FS are working (5FS).

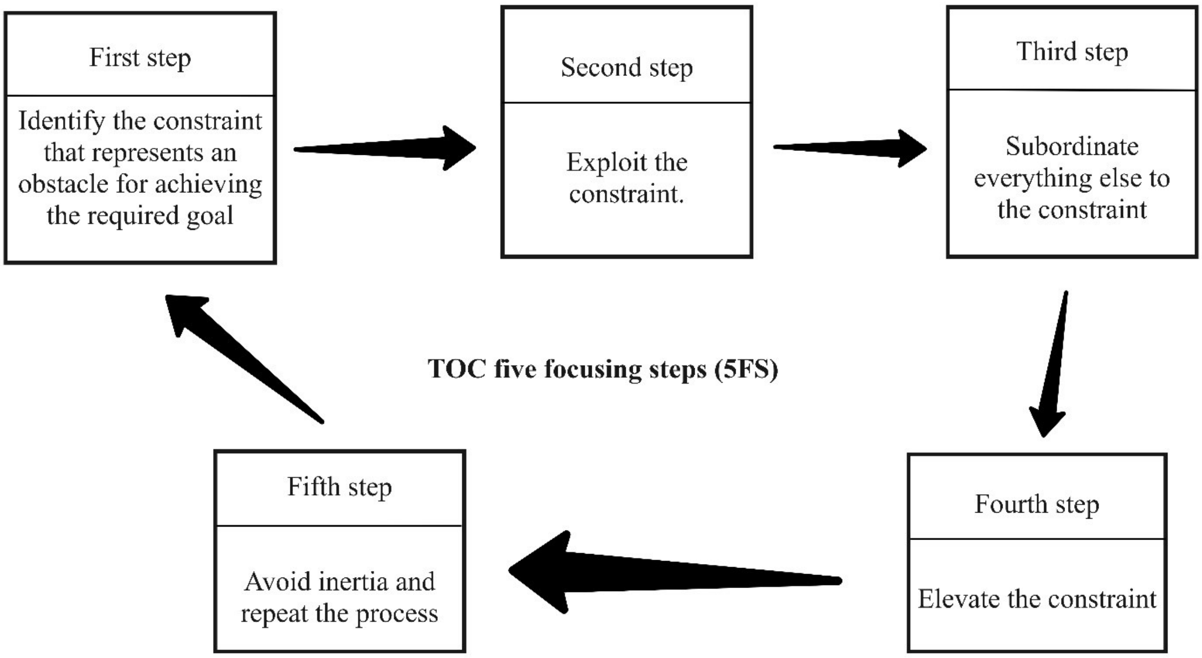


Figure 10: TOC 5FS (Goldratt & Cox, 1992), reformatted by the researcher.

Goldratt and Cox (1984) identify a constraint to be anything that could limit a system from achieving a higher level of performance. Constraints could be classified into physical and non-physical constraints. Physical constraints could be limited production capacity or limited market demand. However, non-physical constraints could be poor managerial policies or poor human behaviours. Cohen (2009) adds that the physical constraints could also be seen as internal and external constraints. An example of an internal constraint could be the lack of production capacity, while an external constraint could be the lack of market buying capacity.

This study will use the TOC 5FS to improve the outcome of dealing with the expected risks due to the GERD by identifying these constraints and focusing efforts on getting the most out of them.

3.4.4.7. Reasons for choosing the TOC tools

There are many reasons to use the TOC in this research. There are also some criticisms that remain valid.

On the one hand, using TOC has proven to be beneficial in many applications: for example, in terms of increasing output and decreasing inventory and cycle time (Watson et al., 2007), increasing due date performance, financial performance, throughput performance, and reducing lead time (Mabin & Balderstone, 2003). Many other important benefits in different sectors have been realised through applying TOC such as manufacturing, services, not-for-profit organisations, and government bodies. These benefits include better management, to be ahead of the planned schedule, reduce multi-tasking and improve its focus, and increase savings (Goldratt & Cox, 1992). There are several other intangible benefits for applying the TOC. It results in less chaos, more order, a faster response, and better customer service (Mabin & Gilbertson, 1994).

On the other hand, Ronen (2005) claims that there are some difficulties and limitations in using TOC, which lead to it having a low profile in academic journals. One reason is that many of the academic journals still prefer quantitative approaches over qualitative ones, while TOC is heuristically oriented, which one of its goals is simplicity. Second, academic journals sometimes prefer studies with empirical data, while the TOC is a cause-effect driven approach. Third, some academics have not been exposed to the TOC's full contribution, because it was created by practitioners. Fourth, the TOC is often misconceived as a simple toolkit that does not require comprehensive research. Fifth, the TOC is only used by certain people (the TOC is viewed as a cult and thus inaccessible to the academic community). This view is supported by Mabin and Davies (2010) who agree that the TOC methods are not yet fully understood or appreciated by some disciplines. They point out the significance of further research regarding the clarification of the philosophical and methodological assumptions in respect to the consistency of the TOC TP tools.

Two other problems have been discussed by Watson et al. (2007) regarding the thinking processes (TP). First, that the TP tools are not user friendly. Second, it involves the user's subjective interpretation of the perceived reality of the subject matter. This subjectivity has the potential to make the trees and diagrams produced by using the TP tools somewhat unreliable.

In this thesis, other tools and approaches have been used to deliver the quantitative results, while the TOC has been used as one of the approaches to deliver qualitative results. One of the reasons behind using the TOC is its nature in studying cause-effect driven relationships, which would be significantly helpful in studying this dispute to understand these causes and its effects. The goal of the TOC is simplicity. However, the TOC itself is not a simplistic toolkit and still requires thorough research. On the contrary, TOC tools require field studies and collecting data, which have been done here through conducting interviews. While some academics have not appreciated the full breadth of the TOC's contribution, due to the focus being on practice over theory, that was not a problem faced in this research given its practical focus. Such focus on practicality was a benefit for this study and provided a suite of tools for analysis through to implementation.

Regarding the TP tools, the challenges faced are no more than other modelling approaches, for example quantitative modelling tools. Any tool or approach takes effort and practice to master. Following this study, the researcher has come to understand that the TOC tools are very useful generally even for day-to-day problems, and their use has become a way of life. For the second problem of involving a user's subjective interpretation, subjectivity is common within qualitative paradigms (Guba & Lincoln, 1994). The judgement of reliability in qualitative paradigms differs from that of quantitative ones. The reliability in quantitative paradigms is judged by the consistency. The consistency is defined as a consistent measuring instrument that measures what should be measured. However, the reliability in qualitative paradigms is judged by the methodological trustworthiness (Guba & Lincoln, 1994). Trustworthiness could be proven through different things, such as: credibility, transferability, dependability, and confirmability (Guba & Lincoln, 1982).

The use of the TOC tools is always guided by a logic known as "Categories of legitimate reservations" (CLR). The use of CLR increases the rigour of analysis; accordingly, it could sometimes be user unfriendly (Mahoney, 2008). The TOC (TP) tools have their own logic-checking protocols, which enhance validity of the logic maps, as will be explained later.

This study will use the TOC 5FS to improve the outcome of dealing with the expected risks due to the construction of the GERD by identifying these constraints and focusing efforts to get the most out of them. The reason for using the 5FS is that there is a clear constraint (water) while the dispute itself can be viewed as a system of inputs and outputs, which has a centralised nature. The 5FS would therefore be applied simply. The 5FS is a practical and useful tool to explore exploiting and subordinating the water-required resources. The 5FS may not work as effectively at managing policies. Despite this, it works well at identifying and managing physical constraints (Cox et al., 2003).

The case under examination is a complicated one that involves many factors affecting the situation. The TOC structures and diagnoses the problem by shaping the constraints and focusing on the roots of the conflict. It also clarifies the challenges that should be overcome to increase the profitability to Egypt through achieving the required goals. The TOC guides the management of the limited resource (water) towards the best place and the best uses to leverage its best return. TOC encourages creative solutions and helps design implementation of them via systematic use of its different tools.

3.5. Ontology and epistemology of different frames and methodologies

Table 4 shows what each tool does for this research. It also explains their ontology in the form of what each tool assumes to exist. The epistemology is covered through three points, which are the way it is represented, the source of data used, and the way this data is used.

				Epistemology		
Analytical frame	Methodology/ Technique	What it does	Ontology (What it assumes to exist)	Represented by	Source of information	How the data is used in the context of this study
Historical analytical frame	A chronological order analysis	Evaluate the historical context of the situation	1- It assumes that progress implies a cumulative advance. 2- Each event is based on its previous relative event (Rotenstreich, 1971). 3- Full awareness cannot imply the consciousness of time in its completeness, “We are always in the midst of time” (Rotenstreich, 1987).	A chronological analysis that defines periods, important events, and their development in order of time	Treaties from literature	1- A comprehensive summary of the previous treaties about the Nile in chronological order is first provided. 2- The historical reasoning approach is then applied to explain the bonds between Egypt and Ethiopia while examining the historical events as a basis of this analysis.
Legal analytical frame	The IRAC method for legal analysis	Evaluate the legal context of the dispute	1- People behave rationally. 2- Laws are committed to some deontological moral principles or anything else for that matter. 3- Laws are consistent until else is proven (Dothan, 2020).	The IRAC framework first defines the Issue and determines the suitable applied legal Rules. It then analyses the issue by applying these rules to deduce a Conclusion (Miller & Charles, 2009)	International water law principles and relevant legal cases from the literature	1- The relevant international water law principles are first explained (Rules), while the details of the Egyptian-Ethiopian dispute over the Nile were provided in Chapter 2 (Issue). 2- The dispute is then studied against these law principles to clarify the legality or illegality of actions, conditions, or intent of both countries (Analysis). 3- Then relevant case law is used to show how international law has been applied to similar disputes (Analysis). 4- This analysis leads to conclude at the end about the legal situation of both parties (Conclusion).

				Epistemology		
Analytical frame	Methodology/ Technique	What it does	Ontology (What it assumes to exist)	Represented by	Source of information	How the data is used in the context of this study
PIM frame	PIM	Identify probabilities and severity of risks to show how bad the problem is	1- Different disciplines view risk or challenge its uncertainties differently which in itself reflects the characteristics of the discipline (Althaus, 2005). 2- Different human perceptions are one of the risks involved in the risk analysis process. 3- Individual beliefs are neutral and have no personal bias until proven otherwise.	Probabilities and corresponding impacts through personal judgment	Interviews and personal experience	1- In this study, the existence of the GERD is considered an actual risk in the real world, while the assessment of its expected impacts is a subjective risk because it is presented through individuals' evaluation in the interviews. 2- International experts have provided their estimates of probability and severity scores of positive and negative risks expected to happen for Egypt due to the GERD from their views.
Decision-making frames	Decision trees/EV DMUCR	Show the actions of the two players in a reactive phase when adopting a certain strategic behaviour to show what options are	1- The rationality of all players. 2- Both players want to maximise their payoffs. 3- Different human perceptions and the real world, which are nondeterministic in nature, affect the decision-making process.	Probabilities and payoffs of event's outcomes could be evaluated	Interviews and personal experience	1- Decision trees are used to organise and represent the collected data for different decision alternatives under conditions of risks. 2- Participants have assigned the Egyptian expected payoff for each outcome and evaluated its corresponding probability. 3- The EV criterion is then used to analyse the data.
	Decision tables/5 criteria DMUCU	Show the actions of one player in a proactive phase to sequence events and uncertainties		Payoffs of event's outcomes could be evaluated, while probabilities unknown	Interviews and personal experience	1- Decision tables are used to organise and represent the collected data for different decision alternatives under conditions of uncertainty. 2- Participants have assigned the Egyptian expected payoff for each outcome, while probability remains unknown. 3- Five different criteria are then used to analyse the data.

				Epistemology		
Analytical frame	Methodology/ Technique	What it does	Ontology (What it assumes to exist)	Represented by	Source of information	How the data is used in the context of this study
TOC frames	GT	It determines the system's goals, CSFs, and NCs for the success	1- Any system must have a goal. 2- This goal defines the direction of this system and determines its ultimate purpose. 3- CSFs and NCs must be identified to achieve this goal.	Necessity logic	Interviews and personal experience	Based on the participants' answers, a GT diagram is created to show the desired goals to be accomplished to mitigate the risks to Egypt's water supply due to the GERD in general and the agricultural sector in particular. In addition, CSFs and NCs derived from the data are articulated.
	CRT	It searches for RCs of the current situation and explains how these lead to UDEs	Current problems, symptoms, cause-effect relations, and UDEs	Cause-effect logic relationships/ sufficiency logic	Interviews and personal experience	1- Two big CRTs diagrams were created to answer the question "What to change?" based on the answers of the participants. 2- The first CRT is used to identify the UDEs to trace down to the currently hidden RCs of the situation regarding the Egyptian agricultural sector in general. 3- The second CRT is used to answer the question in light of the expected risks to Egypt's water supply due to the GERD.
	EC	It focuses on depicting the conflict-blocking solution and finding win-win solutions	Individual beliefs represent opposing views and the different assumptions underlying these views	Opposed viewpoints and their underlying assumptions are represented by necessity logic	Interviews and personal experience	1- The answers of the participants about the conflict have followed three main themes. These three themes are problems/conflicts related to the agricultural sector, and problems/conflicts related to the expected risks to Egypt due to the GERD, while the third kind is problems/conflicts on the national level. 2- The data was used to construct 13 ECs that have covered several dilemmas.

				Epistemology		
Analytical frame	Methodology/ Technique	What it does	Ontology (What it assumes to exist)	Represented by	Source of information	How the data is used in the context of this study
	FRT	It checks that the proposed solutions will really work including devising strategies to avoid potential negative side effects	Problems, actions, and desired outcomes	Cause-effect logic relationships/ sufficiency logic	Interviews and personal experience	1- Three big FRTs were created to answer this question. 2- FRT1 answers the question regarding the current situation of the Egyptian agricultural sector, while FRT2 and 3 answer the question in light of the expected risks to Egypt's water supply due to the GERD in the near future through two different scenarios. 3- The first scenario assumes that Egypt will succeed in having an agreement with Ethiopia to fill the GERD's reservoir slowly, which will not affect the Egyptian Nile's water share. The second scenario assumes that the negotiations between the two countries will fail, and Egypt will have to find other water resource alternatives.
	PRT	It clarifies the obstacles and generates the sequence of actions needed to overcome the obstacles	The existence of obstacles that block the achievement of the desired target	Necessity logic	Interviews and personal experience	Two PRTs are constructed to work on the obstacles expected to be faced when trying to implement the proposed solutions. The first tree works on the obstacles that currently block the proposed solutions to improve the Egyptian agricultural sector. The second tree works on the expected obstacles that would block the proposed solutions to ensure Egypt's survival if the construction and operation of the GERD go ahead as planned.

				Epistemology		
Analytical frame	Methodology/ Technique	What it does	Ontology (What it assumes to exist)	Represented by	Source of information	How the data is used in the context of this study
	5FS	It is a process for continuously improving the output of a system by identifying constraints and focusing efforts to get more out of those constraints	Constraints that limit the system's performance	Process to identify the system's constraints for continuously improving the output	Interviews and personal experience	The constraints that are limiting the achievement of the desired goals of the Egyptian agricultural sector in general and in the light of the expected risks to Egypt's water supply due to the GERD were identified. Then they were exploited, subordinated, elevated, or mitigated its consequences. Finally, the whole process would be repeated in cases where the constraint has been broken.

Table 4: Ontology and epistemology for different frames adapted from Davies et al. (2005).

3.6. Data collection

Yin (2015) states that studying a case requires focusing on each detail, which needs hard effort in collecting data. Different and multiple sources and proofs could be involved.

Given the nature of the research and the type of concepts examined, this research will draw on primary data to serve different purposes as explained below.

3.6.1. Primary data

Hox and Boeije (2005) define primary data as the set of data that have been collected especially for a specific purpose by the scholar. Although the process of collecting primary data is considered costly and time-consuming, its significance in answering the research questions is due to it being totally designed for the studied research. In this research, interviews are used as one tool to collect primary data. These interviews were held in English and Arabic with Egyptian, Ethiopian, and international experts, taking into consideration all the required ethical procedures as will be explained later.

In this study, primary data is required to underpin the various analyses to be conducted – e.g., for the PIM frame. This process determines the likelihood (probability) and severity scores of opportunities and threats due to the GERD. In addition, interviews are held with some of the experts and stakeholders to evaluate the causes, relations, effects, and solutions of this conflict from their points of view, to gain a better understanding of the situation.

3.6.2. Interviews

Hox and Boeije (2005) clarify the interviewing technique is to meet individuals face to face in different communities, where questions are asked, and answers are given. Those individuals have been chosen because they possess knowledge and information related to the topic.

There are many reasons to use this technique to collect data, such as: to attain highly personalised and experienced data regarding a certain phenomenon; to explore new information; to expect a great return rate extent; and when the native language of the majority of the participants is not the language used in the research (Gray, 2004).

A well-designed guide for the interviews, well-planned questions, along with proper interviewers would result in a quality interview being obtained. There are four types of interviews: structured interviews, semi-structured interviews, unstructured interviews, and non-directive interviews (Kajornboon, 2005).

Structured interviews are a standardised set of the same questions that will be posed to all participants in the same order, sequence, and wording (Corbetta, 2003). The main aim of using this type is that the researcher can be certain that all results from different participants of the same level can be aggregated (Bryman, 2016).

There are different levels and nationalities of participants in this study, as will be explained in the next section.

3.6.2.1. Level of participants

In this study, structured interviews were used, with questions separated into five sections. Participants were asked subsets of these questions as explained in Table 5, which includes the kinds of questions, topics covered by each question, and the level of targeted participants.

Question number	Frame covered	Level of interviews	Targeted interviewees	Number of interviews	Nationalities
1 & 2	Personal background	All participants	All participants	All participants	All participants
From 3 to 6	PIM frame	International level	International experts and academics	10 interviews	International and Egyptians (5 different European countries, 1 Other, 2 Egypt, and 2 Upstream Countries)
7 & 8	Decision-making frames (decision trees & tables)	International level	International experts and academics	10 interviews	International and Egyptians (5 Eur, different countries, 1 Oth, 2 Egy, and 2 UpC)

Question number	Frame covered	Level of interviews	Targeted interviewees	Number of interviews	Nationalities
From 9 to 21	TOC (TP tools)	National level	The national government, academics, those in high positions in the agriculture sector, landowners, farmers, industry experts, and other sector representatives & individuals	22 interviews	All Egyptians
From 22 to 26	TOC (5FS)	National level	The national government, academics, those in high positions in the agriculture sector, landowners, farmers, industry experts, and other sector representatives & individuals	22 interviews	All Egyptians

Table 5: Interview questions, frames covered, and participant characteristics.

Two kinds of interviews were conducted. The first was focused at the international level. Questions 1 to 8 covered the participants' personal backgrounds as well as the data required for PIM, decision trees, and decision tables frames. There were 10 interviews with participants varying between several nationalities as follows: 5 participants from 5 different European countries, 2 participants from the two upstream countries (Ethiopia & Sudan), 2 Egyptians and the last participant from a country other than the ones mentioned previously. For analytical purposes, different codes were given for each category as follows: European (Eur), upstream countries (UpC), and Egyptians (Egy), while the final code for the final participant was (Oth). The 10 participants were international experts and academics who specialised in risk management, water laws, water management and agriculture.

The second kind of interviews was focused at the national level, which included questions 1 and 2, in addition to the questions from 9 to 26. The questions covered the participants' personal backgrounds as well as the data required for the TOC frames, TOC TPs and 5FS. There were 22 interviews, all with Egyptian participants. For analytical purposes, the participants were divided into three different categories: governmental/national level, local level, and industry level.

The governmental/national level (coded NL) includes politicians and public servants in both the agricultural and irrigation sectors. The local category (LL) includes local practitioners, such as landowners, farmers, and farmers who own their lands. Industry level (IL) participants are industry experts and academics from either or both the agricultural and irrigation sectors. Six participants of those 22 also belonged to two other categories.

Figure 11 summarises the interviews.

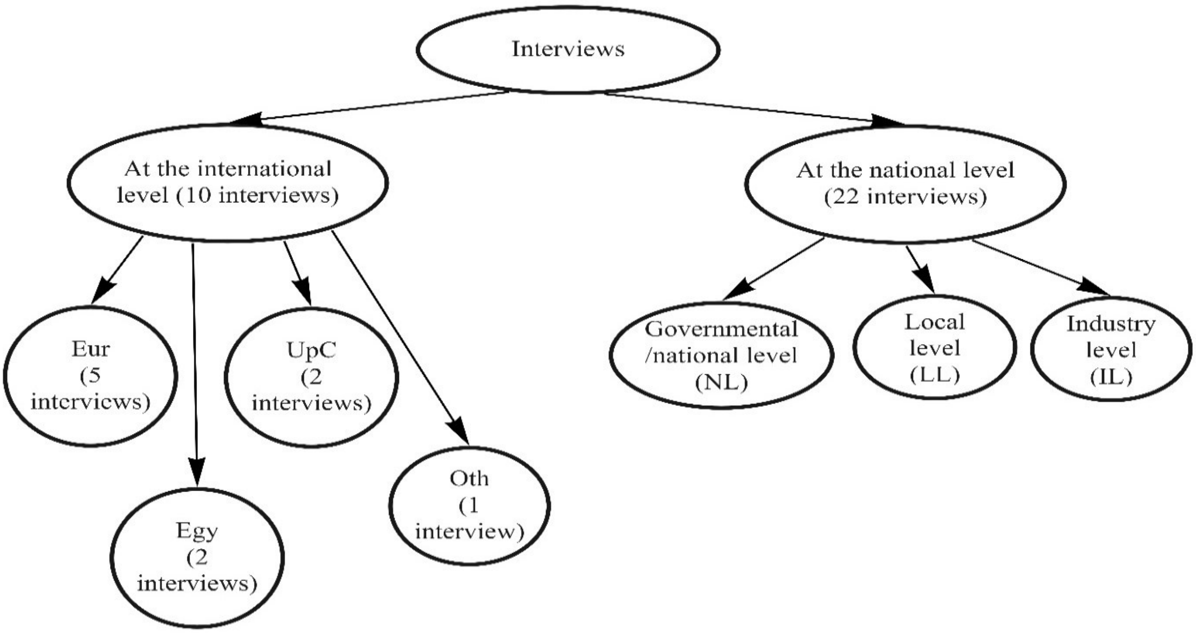


Figure 11: Different kinds of interviews.

3.6.2.2. Participant selection

The international experts and the Egyptian stakeholders were chosen because they possess knowledge and information related to the agricultural sector and are likely impacted by the GERD. Selections were made through my professional and personal networks and knowledge of this field. [1]

Egypt has a unique culture, in which the preferred style of communication is word of mouth. I communicated with my personal networks, who approached and convinced my Egyptian stakeholders to trust me and accept having interviews with me. My personal contacts contacted the participants first and after their acceptance, they linked me directly with them. Egyptian participants were first contacted by telephone call. Then most of the interviews were held face-to-face in Egypt. However, the Covid 19 pandemic raised some concerns relating to face-to-face meetings with some participants, which forced me to

[1] Regarding my professional experience, I am one of the consultants in the risk management field and have worked with many international organisations and companies. In addition, I have been involved in many of water management projects. In 2014, as an engineer, I won the election of the engineering syndicate to become a Council Member at the Egyptian Engineers' Syndicate. I was one of the leaders of the Egyptian revolution in Egypt. At the end of 2011, I was the "Media spokeswoman of the Youth Revolution Coalition" in Alexandria, Egypt. I am therefore well connected to the Egyptian community and have extensive personal networks. At the international level, I am currently the Special Officer of the United Nations of New Zealand (UNANZ) for Humanitarian Affairs as well as being a member of both the executive and national councils of UNANZ.

conduct some of these meetings via Zoom or other communication application technology. International participants were contacted directly by email, and the interviews were held through a communication application technology.

3.6.3. Ethical considerations

Ethical considerations in research are represented through its quality, in addition to guaranteeing anonymity and ensuring the confidentiality of the participants and their personal information. These considerations can be applied through compliance with codes of ethics that are recognised by ethical committees (Flick, 2014). This research required primary data in the form of interviews with individuals. An application was made to the Human Ethics Committee (HEC) of Victoria University of Wellington and was approved before the commencement of fieldwork. The application reference number is 0000028185. The interview guide and the HEC application are attached in Appendix (A). Data collection followed the procedures as per the approved application.

3.6.3.1. Issues encountered and addressed

The ethical issues that arose have been considered and addressed in this section. These issues included objectivity, informed consent and respect for confidentiality, and the human subjects' protection (including the participants and researcher). These issues are discussed below.

- These interviews were held in English and Arabic. English was used during the international interviews, while Arabic was used for the Egyptian and Sudanese interviews. However, there were also times when the Arab participants switched to English, as many of them are professional engineers and technical experts, who have done their studies in English, so English was easier for them to use when discussing technical matters.
- Regarding the technical terms included in the interview questions for the PIM, decision trees and tables frames, the participants of this research were chosen because they possess knowledge and information related to the agricultural sector and the likely impact of the GERD and so they know and are familiar with these technical terms. However, the researcher provided explanations whenever needed, which did not happen often.
- Regarding objectivity, the researcher aimed to avoid bias in all aspects of this research by interviewing people the researcher did not know, or had not worked with, and had no prior relationship with them. In addition, the interview questions and the research were designed to avoid any emotional and psychological disturbance for the participants and stakeholders.
- Regarding informed consent and respect for confidentiality, informed consent means that the participants knowingly, voluntarily, intelligently, clearly and manifestly, gave their consent to participate in the interview after reading the information sheet. The participants were informed that the research findings were to be used for a PhD dissertation, academic publications, presented at conferences, and in professional reports. The researcher also explained the participants' rights to them. The participants had the right to:

    - Accept or reject to participate in the study;
    - Choose not to answer any question;
    - Choose not to have the interview recorded;
    - Choose to record the interview but had the right to ask who can hear it;
    - Ask for the recorder to be turned off at any time during the interview;
    - Withdraw from the study within 48 hours of the interview; and
    - Ask any questions about the study at any time.
- The participants' confidentiality is respected through taking different procedures, as explained below. Furthermore, the participants were reminded that their confidentiality would be protected in this research and the results would only be presented in a manner that ensures confidentiality. Some other procedures were followed to ensure participants' confidentiality, such as:
    - The identifiable information will be destroyed on 01/07/2030;
    - The information is kept confidential to the researcher and supervisors;
    - The recordings are kept confidential to the researcher;
    - No transcriber was used, the researcher transcribed all interviews that required transcription;
    - Participants' names were used in reports and the utmost care was taken not to disclose any information that would identify them;
    - The research data was combined and represented in an aggregate form.
- Regarding the protection of human subjects from harm, the researcher made sure that the participants were not exposed to any harm and maximised the benefits to participants by giving them the right to read the final report of this research if they were to request a copy.
- A safety code was followed to ensure the security of data, such as:
    - Encrypted communication applications technologies, according to each participant's preferences were used;
    - Regarding the intercepted recordings, transcripts, and collected data, the researcher is obligated to protect information from unauthorised access, use, disclosure, modification, loss, or theft;
    - All data collection and storage devices are password protected using a strong password;
    - Access to identifiable data is limited to the researcher;
    - The participants' names were replaced with other identifiers with a unique code and this code was used to refer to the subject data;
    - The code key is stored separately from the subject's identifiers;
    - All recordings were transferred off the recording device immediately after the interview, and the recordings were deleted from the device.
- The researcher wanted to ensure that this questioning would not lead participants to criticise the Egyptian government because the questions are not concerned with governmental behaviours and are not discussing

past plans or actions, but rather future actions. However, some of the participants did offer criticism of the government's performance as a factor affecting the current situation.

- The researcher wrote up the notes for each interview immediately so as not to forget any of the details.

For more details, the HEC documents are attached, see Appendix (A)

3.7. Data analysis

Bryman (2016) defines data analysis as the stage to apply different techniques to the collected data for analysis. She adds, "The data analysis is fundamentally about data reduction, that is, it is concerned with reducing a large body of information that the researcher has gathered so that he/she can make sense of it".

3.7.1. Data pre-analysis strategy in Egypt

This sub-section explains the steps in coding the data for personal interviews at different levels. These interviews were first recorded using an audio recorder, while the researcher was keen on writing some important notes within the interview guide. Some steps were taken after each interview as will be explained below.

1) Participant coding

Data was captured for each participant during the interview. Soon after the interview, each participant was assigned a code based on the category to which the participant belongs. This code was followed with a number denoting the chronological order of interviews. As explained previously, these codes are based on the level and category of each participant. For international interviews, codes such as Eur, UpC, Egy, or Oth were given to reflect the participants' categories.

Additionally, codes such as NL, LL, or IL, were given to reflect the level. The first participant interviewed from the national level is assigned a code NL1 whilst the code LL1 was assigned to the first participant interviewed at the local level. The first participant from the industry level was coded IL1. However, six participants belonged to two different categories concurrently. In these cases, two codes were assigned to the participant, for instance, participant number LL4/IL7 was the fourth participant interviewed from the local level (owns a farm), but he was also the seventh in order at the industry level (one of the sector experts).

2) Transcription and translation of interviews

The researcher transcribed all interviews in the languages conducted. All those in Arabic were then translated into English. The interview transcripts and translations were then stored separately as Word documents. These documents were filed separately using codes as explained before.

3) Excel datasheet

The researcher designed an Excel spreadsheet, which contained similar questions to the ones in the Word document. The researcher then copied the transcribed information from the Word document and pasted it into the Excel spreadsheet. The rows represented different participants, while the columns indicated the interview questions and responses of each participant to a particular question. Each Excel spreadsheet represented one of the used tools or frames in this study.

The difference between the Excel and Word documents was that the Excel spreadsheet could hold all the transcribed data for all participants to display them together as a single sheet for each frame. Indeed, the format of Excel facilitated the easy comparison of responses across a particular question or participant or even to capture all views together. Therefore, after every transcription, and translation if it was needed, the researcher transferred data into the Excel spreadsheet. The arrangement of the data in such a way allowed for a systematic approach to the analysis.

3.7.2. Data analysis approach

Each perspective and framework used in the study have different representation and analysis techniques associated with it. Each framework prescribes its own type of analysis depending on the tool used and its focus. The historical perspective is analysed through a literature review representation. This analysis is applied by using historical reasoning to explain how the treaties affect the two countries; moreover, illustrates both countries' views. The legal perspective is also represented through a literature review. It is analysed by explaining the international transboundary water laws relating to the conflict. The analysis is continued through shedding light on the legality, or illegality of actions, conditions, or intent of the two countries' actions.

The PIM frame and decision trees and tables frames are represented through mapping and tables. The frames depend on the primary data that was collected during interviews. The analysis of these maps and tables led to specific findings. For example, in the decision analysis frame, the decision tables and trees were analysed to show different kinds of actions, which could be taken depending on the nature of the conflict. It showed a sequence of events and the options available to both parties, as will be explained in detail in Chapter 6.

The TOC analytical frames guided its data analysis strategy. The TOC TPs tools are represented through logic maps. These maps first represented the problem, then analysed, diagnosed, devised solutions, and devised implementation, according to the specific protocols for each of the TOC logic tools. The researcher used the Miro software program, which is a visual collaboration platform designed for creating and constructing different flowcharts, such as the TOC TPs logic trees.

3.8. Validity

Winter (2000) argues the definition of the term "validity" in research. Winter claims that the validation concept could include different meanings. There is no single consolidated concept that explains this term. In any research, the validation process is affected by the research intentions, methodologies, and approaches. Maxwell (1992) identifies different types of validation, in different research phases, such as descriptive validity, theoretical validity, and evaluative validity, as explained in the next sub-sections.

3.8.1. Descriptive validity

Descriptive validity is concerned with the first phase of research, including the data-collecting process. It focuses on actual accuracy in the information collected to depict the observations and experience. This accuracy could be presented in the chosen language and the methods used to select data appropriate to the matter (Maxwell, 1992).

Descriptive validity was applied in this study through validating the interview questions. For example, for the interview questions relating to the TOC, questions from 9 to 26 comprise a standard set of questions which have been adopted by many scholars, such as Dettmer (2007) and Cox et al. (2003). These questions were designed carefully as the minimal set of questions that are both necessary and sufficient to construct the TOC diagrams. This set of questions has been used in at least six other PhD theses at Victoria University of Wellington under the supervision of Prof. Vicky Mabin.

The data obtained for this research through interviews were conducted in English and Arabic. The English versions of the HEC documents were checked by the supervisors and the student-learning department at Victoria University of Wellington. They considered the documents to be both semantically and grammatically correct while maintaining a style that was Arabic friendly. The researcher, as a native Arabic speaker, prepared versions in Arabic. As explained previously, English was used in the international interviews, while Arabic was used in the Egyptian and Sudanese interviews. However, there were also times when Arab participants used English, because many of them had done their studies in English, so it was easier for them to use English when discussing technical matters.

The researcher was keen to maintain the accuracy of the data collected by ensuring that technical terms are known to the participants before answering the questions. The researcher provided explanations whenever needed, though this did not happen often because all participants were experts in the field of study.

3.8.1.1. The quality of data obtained

In a multi-framing study like this, a saturation of data, especially related to a qualitative approach is considered a reflection of data quality. Saturation of data means the point that the researcher feels satisfied and confident that no significant new data would emerge from further interviews. This is usually used to limit the number of interviews undertaken. In the thesis proposal, 6 interviews at the international level and 10 interviews at the national level were envisaged. However, the researcher interviewed 10 participants at the international level and 22 participants at the national level as additional stakeholders at different levels volunteered and wished to express their views and concerns. Some of the extra interviews added different results. However, the final interviews did not. That is when the researcher felt satisfied and confident that no significant new data would emerge from further interviews. It became clear how well the themes were being addressed and how participants started to repeat themselves or echo other participants. Once the researcher found many similarities and voices echoing each other, there would be no benefit in adding participants or extending interviews.

In terms of data saturation, the nature of data obtained for each category of the three at the local level showed that participants largely shared similar perspectives and concerns about issues affecting the sector. At the governmental/national level, for instance, issues and concerns related to the same aspects were raised by participants. These aspects were more concerned with the bigger picture of the whole country, for example, issues like climate change and the emigration of skilled workers. As was explained previously, this category included politicians and governmental public servants in both the agricultural and irrigation sectors.

The same can also be said about participants at the local level and those who were interviewed at the industry level. The issues that were raised by participants at the local level were more realistic and concerned with details, for example, the issues related to agricultural practices and irrigation methods. This category included local practitioners, such as landowners, farmers, and farmers who own their lands. In the third category at the industry category, which included industry experts in both agricultural and irrigation sectors, the participants were more concerned with issues related to the industry itself, for example, the unemployment rate.

Representative views were thus sampled, reported, and categorised. The researcher noted for interviews at the national level that the final seven interviews were almost repeating the same views declared by other participants. It became clear that saturation had been achieved, while the repetitive pattern of participants' views at the end confirmed and validated the data of earlier participants.

3.8.2. Theoretical validity

Theoretical validity is concerned with the quality of the research itself. It focuses on the applied construction to ensure that it reflects the measures that the researcher intended to study. Generalisability is a type of validation that could exist in some studies but not all. It describes the ability to extend the research findings to wider groups (Maxwell, 1992).

The theoretical validity relies on the individual frame analysis as well as the integration. Hence each frame will be considered in turn. In the context of this study, the theoretical validity of the individual frame analysis relies on reviewing the contextual literature related to the study.

The literature review of this study first defined the research gap. It helped the researcher to gain a better understanding of the existing situation to enhance the quality of the research. Moreover, the first two frames of this study were represented as contextual literature to offer all available information about the historical and legal aspects of the Egyptian-Ethiopian conflict.

The quality of the research also stems from the design of the multi-framing approach. The researcher has confidence that the chosen frames in combination have achieved the goals required for this research. Moreover, the researcher has depended on her personal and professional background, her knowledge of risk management and the Egyptian situation, and her neutrality. Attending conferences and contributing to publications related to the study help to further prove the quality of the research, as explained in the next subsection.

3.8.2.1. Conferences and publications relevant to the study

Attending conferences and being accepted for publication in journals related to the study are ways to gain feedback on the quality of the research. It also helps in updating the researcher's knowledge and providing an opportunity to present her work and listen to academics' opinions.

One main conference took place during the period of research. The 11th Annual Australasian Bayesian Network Modelling Society (ABNMS) Conference on the theme "Risk and Decision-Making" took place in Wellington, New Zealand, (13-14 November 2019). This conference brought together many international experts in risk and decision-making fields and discussed wide-ranging issues pertaining to state-of-the-art approaches to risk and decision making.

The researcher participated in this conference and gave a poster presentation about the topic and techniques used in this research, which in turn opened many discussions with other experts about a multi-framing approach.

Sadly, the impact of the Covid 19 pandemic has prevented the researcher from attending other conferences because most of them were postponed.

The researcher has submitted three papers for publication. One has been accepted for publication in Africa Today, which discusses the historical frame used in this study. The second and third papers have been presented and published in iCWEE, in November 2022, in Sydney, Australia. These two papers discuss the legal frame and the use of this multi-framing approach for studying disputes over shared watercourses for better outcomes. These are:

- Youssef, A., Mabin, V., & Howell, B. (2023). The Egyptian-Ethiopian dispute over the Nile: Lessons from the past for future African peace and prosperity. *Africa Today, 69*(4), (forthcoming).
- Youssef, A., Howell, B., & Mabin, V. (2022). The Egyptian-Ethiopian dispute over the Nile: Analysis and suggested approach against the background of international water law principles and relevant case law. *In Proceedings of 3rd International Conference on Water and Environmental Engineering (iCWEE 2022)*, November 2022, Sydney, Australia, 9-14.
- Youssef, A., Mabin, V., & Howell, B. (2022). Analysing disputes over shared watercourses using multi-framing: The case of the Egyptian-Ethiopian dispute over the Nile. *In Proceedings of 3rd International Conference on Water and Environmental Engineering (iCWEE 2022)*, November 2022, Sydney, Australia, 15-20.

3.8.2.2. Validity and logical soundness of TOC tools

Categories of Legitimate Reservations (CLRs) is a set of logic rules that guides the construction and use of the TOC maps. The use of the CLRs increases the rigour of the study's analysis as well as clarifies the chain of logic (Mahoney, 2008).

The TOC tools use two logics to represent relationships and surface and challenge assumptions, namely necessity and sufficiency logic. Necessity condition logic describes the needed requirements or prerequisites to have a desired outcome, such as GT and EC, while sufficient condition logic represents effects as a logical outcome of certain causes, such as CRT.

The CLRs consist of a framework of eight specific tests as follows (Dettmer, 2007):

1. Clarity: It checks the complete understanding of an idea to ensure its clarity in the meaning of statements and within its context.
2. Entity existence: An entity is a statement that represents a complete idea. This entity (cause or effect) should represent one idea that is grammatically correct, while avoiding embedded "if-then" statements. The content of the entity should have real meaning and sound reasonably acceptable to the listener.
3. Causality existence: Ensure that the stated cause unavoidably leads to the stated effect, where an "if-then" relationship is applied.
4. Cause insufficiency: It signifies a missing "and" condition. In other words, it checks if the cause is enough to produce the stated effect, or if there are other required conditions for the stated cause to lead to this effect.
5. Additional cause: It signifies a missing "either/or" condition. In other words, it is concerned with the existence of a completely independent and separate cause of a certain effect.
6. Cause-effect reversal: It checks if the proposed cause is a real cause rather than an indicator. It checks the misalignment of cause and effect.
7. Predicted effect existence: It checks if there are some other unstated expected effects of the cause and if the cause-effect relationship is proven valid.
8. Tautology (circular logic): The existence of effect is offered erroneously as a rationale for the existence of the cause.

The researcher has used CLRs to validate the cause-effect relationships shown in the TOC logic trees. CLRs logic-checking protocols enhance the validity of the findings of the TOC logic diagrams/trees, which consequently enhances the validity of the overall findings of the research.

My supervisors have checked all the TOC diagrams to confirm cause-effect logic. Moreover, the researcher presented and discussed the diagrams with two of her postgraduate fellows who had already obtained their research degrees and used TOC as one of the methodologies for their theses.

3.9. Summary

This chapter started with a justification of the critical realism ontological philosophy that underpins mixed method research and the case study design adopted in this study. It then provided an overview of the multi-framing approach and individual frames and the reasons behind choosing these frames. It has described in detail each of the analytical frameworks, methods and tools that are used in the analysis, which is covered in Chapters 4 to 7. To sum up, Table 6 provides a summary of the perspectives, frames, methods, tools, and data that were explained in this chapter.

Perspectives	**Frames used**	**Methods/tools used**	**Data source**
Historical perspective	Historical analysis frame	Use historical reasoning to illustrate the bonds between both parties	Treaties from literature
Legal perspective	Legal analysis frame	The international transboundary water laws relating to the conflict between Egypt and Ethiopia	International water law principles and relevant legal cases from the literature
Risk perspective	PIM frame	Probability and impact matrix	International interviews
	Decision trees frame	Decision trees and EV	International interviews
	Decision tables frame	Decision tables and 5 criteria	International interviews
TOC perspective	The TOC five TPs frames	Goal Tree (GT)	Local interviews
		Current Reality Tree (CRT)	Local interviews
		Evaporating Cloud (EC)	Local interviews
		Future Reality Tree (FRT)	Local interviews
		Prerequisite Tree (PRT)	Local interviews
	TOC 5FS frame	5 Focusing Steps (5FS)	Local interviews

Table 6: Summary of used perspectives, frames, methods, and tools.

Moreover, this chapter has discussed data type, data collection techniques, ethical considerations, and the approach to data analysis that has enhanced the credibility of the research. The next chapter presents the analysis from the first frame, the historical analytical frame.

Chapter 4
Historical Perspective

4.1. Introduction

Differing interpretations of the concluded treaties and agreements over the Nile are a key driver of the current dispute between Egypt and Ethiopia. The historical analytical frame explores past events enabling and aiding understanding of the current situation.

This chapter comprehensively summarises all previous treaties regarding the Nile waters, as an essential foundation for understanding the current dispute between Egypt and Ethiopia. A chronological analysis is applied in this study, which provides two benefits. First, it explores historical events by providing a narrative describing the events and treaties throughout the historical period. Second, the chronological analysis provides insights drawn from the narrative.

4.2. Analysis of the historical analytical frame

Colonial-era and post-colonial treaties over the past two centuries have played a significant part in the Egypt-Ethiopian dispute.

4.2.1. Nile River Treaties during the colonial-era (from 1891 to 1929)

4.2.1.1. Anglo-Italian Protocol (1891)

Britain (on behalf of Egypt and Sudan) and Italy (on behalf of Eritrea) signed the Anglo-Italian Protocol on 15 April 1891. The purpose was to delimit the colonial boundaries between Britain in Sudan, and Italy in Eritrea. The British motive was to protect its colonial interests in Egypt at the time. However, Article III of the Protocol discussed the Nile's water as an incidental issue (Abdo, 2004).

The Protocol professes the British policies to fully control the Nile's water (Tafesse, 2011). Article III, No. 136 prevented Italy from executing any construction at the headwaters of the Nile which might "sensibly modify" the water flow (Trozzi, 1983). This vague phrase has not limited the use nor the fair share of the Nile. This Protocol did not mention upstream States, such as Ethiopia, as Italy did not at that time have colonial interests there. Nor did it preclude the upstream States from using the Nile's water.

The Protocol remains a bilateral agreement, with no effect on other States. Nonetheless, it shows the importance of the Nile for the whole region and for the colonial powers that have sought to control it.

4.2.1.2. Anglo-Ethiopian Treaty (1902)

The main purpose of the Treaty was, like the Anglo-Italian Protocol, the delimitation of boundaries between Ethiopia and Sudan. However, some matters related to the Nile's water were discussed in Article III (Abdo, 2004).

While Britain represented Sudanese interests, Ethiopia was an independent sovereign kingdom. The negotiations resulted in the signing of a treaty on 15 May 1902. However, conflict subsequently arose from differences in the two languages that were used in writing two versions, English and Amharic, the official Ethiopian language (Ferede & Abebe 2014).

Under Article III Ethiopia agreed not to execute or allow any works, without the permission of the British government (Abdo, 2004). The English version of the Treaty stated that Ethiopia should secure permission from both British and Sudanese governments to implement any construction projects that would "arrest" the flow of the Blue Nile or any of its tributaries while the Amharic version stated that they should only secure the permission of the British government (Ferede & Abebe, 2014). Additionally, the word "arrest" is interpreted differently in Amharic and English. In the Ethiopian version, the word "arrest" means to prohibit the whole water flow; it does not mean to stop the water itself (Abdo, 2004).

Some claim that this treaty was a "British wicked deception" to fully control the Nile waters, by first invading Sudan in 1898, and then striking "this deceitful treaty" with Ethiopia (Tafesse, 2011). Others argue that neither Ethiopia nor the British Parliament ratified the Treaty, and hence it was not legally binding (Tafesse, 2011; Ferede & Abebe, 2014).

Tafesse (2011) argues that the main aim of the British in using the phrase "without the British government's permission" was a hidden motive to be able to punish or inflict a penalty on Egypt at some later point by controlling the Nile's flow. Ferede and Abebe (2014) propose that the British concluded this Treaty to stop any of their colonial competitors from extending control over the Nile, and to restrict Ethiopia's rights in concluding any other treaties, which showed the British fears, and their underestimation of Ethiopia. They argue that Egypt cannot claim any rights using this Treaty because it was between Ethiopia and Britain representing Sudan. They also allege that Ethiopia signed under colonial pressure, which could be considered unethical.

Regarding the current conflict, Ethiopia strongly refutes the Treaty stating that it was invalid due to the failure to have it ratified and linguistic differences. Egypt insists that this Treaty is valid, with Ethiopia not authorised to implement any construction on the Nile's water without Egyptian government permission, as Egypt is the successor State to the British (Salman, 2013a).

This Treaty remains one of the most debated treaties in the modern history of the Nile. Both Egypt and Ethiopia claim that they have the rights and own the correct understanding of the Treaty, which authorises each to maintain its current position. In Ethiopia's view, the phrase "arrest the Nile flow" could not be interpreted as forbidding Ethiopia from using the Nile's water as this would require it to maintain the interests of the downstream countries to the exclusion of engaging in activities using the water that would benefit itself. Yet Egypt views that it has historic rights to the Nile flow and that Ethiopia did not claim its rights to the water until very recently. Egypt refutes claims that Ethiopia was coerced into signing because Ethiopia was an independent free nation at the time. Ethiopia could have claimed rights to the water then had they been so inclined.

4.2.1.3. Anglo-Congolese Treaty (1906)

In May 1906, Britain and the Independent State of the Congo signed the Anglo-Congolese Treaty. Article III forbids the Independent State of Congo from executing any constructions on the White Nile and its tributaries (Semliki or Isango River) that would decrease the White Nile's flow into Sudan and downstream States without first obtaining the Sudanese Government's permission (Swain, 1997; Okoth-Owiro, 2004).

As with the previous treaties, the aim was to secure British colonial interests in the Nile. Most of the Nile basin States were at that time under British colonial rule either directly or indirectly (Tafesse, 2011). Whereas the Anglo-Ethiopian Treaty enabled British control of the Blue Nile., the Congo Treaty allowed control of the White Nile. Although the downstream countries were not direct parties to the Treaty, it favoured them by restricting the use of the Nile water by the Congo.

4.2.1.4. Tripartite Treaty (Anglo-Italian-French) (1906)

In 1903, negotiations started between Britain and Italy to align their common interests in Eastern Africa by taking control of and partitioning Ethiopia to strengthen their authority and protect their colonies. Subsequently, France joined the discussion. Each of the three European forces was afraid one of the others might take control of Ethiopia; therefore, splitting Ethiopia into spheres of influence was the best solution for each party (Marcus, 1964). While the initial draft of the Treaty was finalised in July 1906, Ethiopian Emperor Menelek objected to the Treaty as it would marginalise his power and diminish his authority. Endeavours by European powers to persuade the Emperor to sign proved futile; regardless they signed the Tripartite Treaty in December 1906 (Marcus, 1964).

Despite not acknowledging Ethiopia's sovereignty over its territory, nor involving Ethiopia as a party, this Treaty brought Ethiopia into a more peaceful era. It stopped France and England's colonising activities in the African Horn while constraining Italian growth for a period.

4.2.1.5. Anglo-Italian Secret Treaty (1925)

The Anglo-Italian Secret Treaty comprised a covert exchange of notes between Britain and Italy (Ferede & Abebe, 2014). These notes were to confirm the previous Egyptian and Sudanese rights to the White and Blue Nile headwaters; moreover, the emphasis was on not allowing any construction or projects that would affect these headwaters or influence the Nile's flow (Okoth-Owiro, 2004).

These notes gave an assurance of Italian support to Britain to secure Ethiopian approval for constructing a dam on Lake Tana and to secure Ethiopian approval for constructing a road connecting Lake Tana to Sudan to transfer British goods. In return, the British agreed to support Italy to secure Ethiopian approval for constructing a railway from Eritrea's border to Italian Somaliland's border (Ferede & Abebe, 2014).

Upon discovery of the exchange, Ethiopia protested to the League of Nations about the egregious infringement of its rights. Britain and Italy asserted that their notes were misconstrued, and their actions were not in breach of Ethiopian sovereignty (Ferede & Abebe, 2014).

4.2.1.6. Anglo-Egyptian Treaty (1929)

The Anglo-Egyptian Treaty was an exchange of notes between Egypt and Britain representing its colonies, Sudan, Uganda, Kenya, and Tanganyika (now Tanzania). Egypt agreed to increase the Sudanese share of the Nile's water to support Sudan's development. The uncertainty of Sudan's political future at that time; the weakness and disinterest of most of the basin States, and the overwhelming weight of British authority in the region were all significant factors at the time that affected the overall situation.

The Treaty divided the water into 48 bcm for Egypt, and 4 bcm for Sudan; a ratio of 12:1 in favour of Egypt (Tafesse, 2011). Additionally, a surplus estimated at 32 bcm remained unassigned, ostensibly that 32 bcm was not allocated to any of the Nile basin States to refute other States' counterclaims and dismiss accusations of the British bias because of its interests (Ferede & Abebe, 2014).

Egypt agreed to the conditions:

- This increase would not affect Egypt's historical and normal share of the Nile water, nor the water needed for the expansion of its agricultural areas (Carroll, 1999).
- Britain undertook on behalf of its colonies not to implement any projects on the Nile that could affect or reduce the Egyptian share.
- Egypt has the right to check any work along the Nile.
- Egypt has the right to monitor the flow of the Nile in Sudan, accompanied by the right to use the whole flow whenever necessary.
- Egypt has the right in executing any works on the Nile without asking permission from any of the other basin States.
- A veto right was given to Egypt to stop the construction of any project on the Nile (Tafesse, 2011).

This Treaty explicitly clarified Egyptian historical rights of the Nile, separate and distinct from colonial interests. Significantly, most of the other basin States have not subsequently asked for allocations of the reserved water, even after gaining independence.

4.2.1.7. Consolidated and supplementary agreements of the 1929 Treaty

Treaties signed as supplementary agreements of the 1929 Treaty reflect the importance of the Nile's water for Egypt, even though they do not all directly affect the dispute between Egypt and Ethiopia.

The first supplementary agreement was signed between Egypt and Sudan in 1932. The Anglo-Egyptian administration in Sudan approved the construction of Jebel Aulia Dam on the White Nile in Sudan to store water for Egypt's exclusive use (Wassara, 2014; Degefu, 2003). Egypt funded the dam's construction and maintenance (Kidd et al., 2014), with the water used primarily for British-owned Egyptian cotton agriculture (Wassara, 2014).

Another supplementary agreement was signed between Egypt and Sudan late in the same year compensating the Sudanese for the damage caused to Sudanese lands because of the dam (Degefu, 2003). While Egypt and Sudan were parties to the agreement, British colonial interests were the beneficiaries.

The third was the Anglo-Belgian Agreement in 1934, which divided the Kagera river's waters between Burundi, Rwanda, and Tanganyika (Tanzania) (Kidd et al., 2014).

The fourth was the Lake Tana agreement in 1935. Egypt and Sudan came to an agreement regarding their interest in the construction of a new dam on Lake Tana in Ethiopia. Both parties agreed to construct and run the dam for their own benefit. They agreed on the condition of gaining Ethiopia's acceptance. As the two parties could not secure the Ethiopian approval, the agreement stayed null and void (Degefu, 2003).

The fifth was the Tripartite agreement (Anglo-Irish-Egyptian Agreement 1950). This Treaty was represented by the exchange of notes between the United Kingdom of Britain and Northern Ireland (on behalf of Uganda) and Egypt in February 1950. The main purpose of this agreement was to establish a common ground for cooperation between the three parties regarding the meteorological and hydrological studies, scanning and observations for some areas of the Nile basin (Kasimbazi, 2010). This agreement aimed to keep Egypt well informed about the updates that could occur in the upstream countries. This shows that Egypt has always held feared what may happen upstream.

The sixth was the Owen Falls Agreement – an exchange of notes between Britain (representing Uganda) and Egypt, regarding the construction of two dams on the White Nile in Uganda (Okoth-Owiro, 2004). This agreement was accomplished in three phases. The first exchange on 30 May 1949 discussed the generation of Ugandan electricity. The second was on 5 December 1949 to approve the contract. The third exchange of notes was an agreement organising the financial settlements on 5 January 1953 (Kasimbazi, 2010). The conditions were: the dam's construction would be under Egyptian supervision; the dam would be managed by the Uganda Electricity Board but through Egyptian instructions; and this agreement would be contraindicated if it contradicted the 1929 Treaty (Okoth-Owiro, 2004).

4.2.2. Post-colonial Nile River Treaties (from 1959 until present)

4.2.2.1. The Egyptian-Sudanese Treaty (1959)

The Republic of Sudan attained independence in 1956. As an assertion of Sudanese independence, the first Prime Minister asked for reconsideration of the division of water under the 1929 Anglo-Egyptian Treaty. Egyptian President, Gamal Abdel Nasser also wanted to revisit the Treaty given the pending construction of the Aswan High Dam AHD which would submerge some Sudanese land (Tafesse, 2011).

An agreement was reached in November 1959 following a Sudanese coup. This Treaty divided the total annual flow of the Nile into 55.5 bcm assigned to Egypt, 18.5 bcm assigned to Sudan, and 10 bcm assigned to the evaporation and leakage of the Egyptian dam's reservoir. This arrangement greatly benefited Sudan, with a ratio of 1:3, instead of 1:12 as stipulated in the 1929 Treaty. Furthermore, requests from upstream countries for water access must be discussed and agreed upon by Egypt and Sudan together, with any reallocations taken equally from the Egyptian and Sudanese shares (Tafesse, 2011).

The Treaty served multiple purposes. There have been two views concerning this Treaty. First, the Egyptians needed Sudanese approval and secure water rights to attract investment for the AHD (Tafesse, 2011). The Sudanese needed Egyptian approval to construct the Roseires Dam on the Blue Nile (Waterbury, 1994) as a condition of obtaining WB finance for the Roseires Dam and relocating the Nubian Sudanese people (Tafesse, 2011). The agreement was brokered by and obtained the support of the WB.

This Treaty united Egypt and Sudan around their mutual goals related to the Nile but simultaneously isolated them from the rest of the basin States who felt their rights had been overlooked. The situation became more complicated after South Sudan gained independence from Sudan in July 2011. While an argument could be made for using the international law "principle of state succession", nothing can force South Sudan to be bound by this Treaty.

Different meetings and trials have been launched to found basin-based cooperative initiatives since the mid-1960s (Salman, 2013a). These are described next.

4.2.2.2. Hydromet Project Initiative (1967)

The Hydromet Project was established in 1967 by Egypt, Sudan, Kenya, Tanzania, and Uganda in cooperation with the United Nations Development Programme (UNDP) and the World Meteorological Organisation (WMO) (Swain, 2002, 2011). Burundi and Rwanda have joined this project subsequently (Schoeters, 2013).

The main purposes were observing the water balance of Lake Victoria; and hydrometeorological surveying of the Great Lakes region, Lakes Victoria, Kyoga, and Mobuto Seseko (Schoeters, 2013; Swain, 2002, 2011). Disappointing results led to the UNDP's withdrawal in 1982 (Schoeters, 2013). The members of the project funded it by themselves from 1982 until its completion in 1992 (Swain, 2002).

Although this project failed to achieve tangible results, it was considered the first attempt to establish Nile basin cooperation fostered by international mediation.

4.2.2.3. The Undugu Initiative (1983)

The Undugu Initiative was formed in 1983 by Egypt (the prime mover), Sudan, the Democratic Republic of Congo, Uganda, and the Central African Republic. Tanzania, Kenya, and Ethiopia were invited as observers. This Initiative created a platform for discussion of the economic enhancement of the White Nile region (Schoeters, 2013). Egypt as one of the most influential countries in the region has fully realised the importance of cooperation between the Nile's basin States. Egypt demonstrated its leadership and influence in the Nile affairs by launching this initiative (Schoeters, 2013).

This Initiative was renamed "Technical Committee for the Promotion of the Development and Environmental Protection of the Nile Basin" (TECCONILE), in 1992, during meeting number 67, attended by now-members Egypt, Sudan, Uganda, Tanzania, Rwanda, and the Democratic Republic of Congo, with the rest of the basin States as observers (Jönsson, 2013; Swain, 2002, 2011). The Nile River Basin Action Plan (NRBAP), which focused on the economic development of the basin, was the most significant output of TECCONILE (Schoeters, 2013). Other activities have included "Nile 2002 conferences" and technical experts' meetings launched in 1993 and continued until 2002 (Nicol & Shahin, 2003).

These initiatives have focused on scientific and technical issues, not legal conflicts, and not all Nile basin States have been included (even as observers) so they have not had a noticeable effect on Egypt-Ethiopia conflict (Schoeters, 2013; Cascão, 2009).

4.2.2.4. The Nile Basin Initiative NBI (1999)

Regional economic cooperation among basin States has been recognised as key to success for the whole region since the 1990s. The ever-increasing demand for water, its allocation, and its distribution have underpinned the need for cooperation (Swain, 2011; Schoeters, 2013). In 1999, the Nile Basin Initiative (NBI) – an intergovernmental partnership (Salman, 2013a) - replaced NRBAP and TECCONILE (Cascão, 2009; Swain, 2002, 2011; Jönsson, 2013; Schoeters, 2013).

The NBI is the first initiative to include all ten Nile basin States of the Nile basin (eight originally with Eritrea as an observer and South Sudan joining in July 2012) (Cascão, 2009; Swain, 2011). The aim is "to achieve sustainable socio-economic development through the equitable utilisation of, and benefit from, the common Nile basin water resources" (Nile Basin Initiative, n.d., para. 2; Cascão, 2009; Swain, 2011).

Its two subsidiary action programs are: the Subsidiary Actions Program (SAP) covering two sub-basin investments, the Eastern Nile Subsidiary Actions Program (ENSAP) and the Nile Equatorial Lakes Subsidiary Actions Program (NELSAP) (Nile Basin Initiative, n.d.), and the Shared Vision Program (SVP) focused on obtaining investment to enhancing the environment and build confidence (Cascão, 2009; Schoeters, 2013). WB, UNDP, and Canadian International Development Agency (CIDA) funded this latter initiative alongside the basin States (Jönsson, 2013).

4.2.2.5. The Cooperative Framework Agreement (CFA) 'Entebbe Treaty' (2007)

The CFA was signed in Entebbe, Uganda in 2007 (Salman, 2013a). It aimed to create a united permanent legal agreement including all of Nile's basin States

(Cascão, 2009; Jönsson, 2013) that addressed legal and institutional aspects excluded from previous agreements due to their contentious nature (Schoeters, 2013). This agreement founded a permanent organisation Nile Basin Commission (NBC) to supersede the NBI (section 4.2.2.4) (Cascão, 2009; Swain, 2011).

Seven of the Nile's basin States, Rwanda, Uganda, Burundi, Ethiopia, Tanzania, Kenya, and the Democratic Republic of Congo, signed and ratified the agreement in 2010 (Swain, 2011). Egypt and Sudan refused to sign the CFA as it would replace the Egyptian-Sudanese 1959 Treaty (Jönsson, 2013). The Egyptian Minister of Water Resources and Irrigation described it as a request to the Egyptians to give up their culture and lives.

4.2.2.6. A change in the political context

In a changing political context (South Sudan's independence (2011) and the Egyptian revolution (2011)) and without Egyptian and Sudanese support, the CFA was unable to stop a growing number of unilateral programmes, of which the GERD is an example (Schoeters, 2013). These programmes were not announced or included in any previous agreements and were not accepted by the downstream States (Jönsson, 2013).

Following Egypt and Sudan's objections to the GERD, the Nile Tripartite Committee (NTC), was established in November 2011 to assess the effects of the GERD on Egypt, Sudan, and Ethiopia. It consisted of ten experts: two representatives from each country and four international experts (Jönsson, 2013). The panel's report, signed by all ten members was issued in May 2013.

4.2.2.7. The Nile Tripartite Committee (NTC)

The report found various problems related to the analysis and documents presented by Ethiopia regarding the dam and criticised a lack of analysis on several critical issues. These included (International Rivers Org, 2013):

- Quality of project documents: Designs presented to the panel were general, with no specifications or site-specific conditions. The design report was outdated and did not include significant changes to the project.
- Safety: The panel asked for more analysis, as it did not have permission to access all information required to check the dam's safety. Some engineering assumptions were questioned (e.g., shear strength) and concerns were raised (e.g., sliding, seepage). Design modifications for some parts of the dam were suggested.
- Changes to flow for the downstream States: The GERD was found to allow for the expansion of Sudanese irrigated cropping, which would decrease flows to Egypt. A detailed study on this issue was requested.
- Environmental impacts and climate risks: The studies of the impacts on local people, ecosystems, fisheries, biodiversity, or climate were very limited. The chosen height of the dam did not consider the impacts on downstream States' environmental and socioeconomic situations. The project depends on heavy rainfall patterns, which requires a better understanding of future hydrologic conditions to

ensure harm is not caused to downstream States, especially during drought conditions.

- The operation process: Very limited data was given.
- Additional studies were recommended to "quantify the downstream impacts in detail with confidence". These included an assessment of the environmental and socioeconomic effects and a simulation model on water resources/hydropower systems (International Rivers Org, 2013).

On 28 May 2013, three days before the NTC published its report, Ethiopia diverted the Blue Nile to start constructing the GERD. This has been interpreted as signalling Ethiopian intentions to proceed with the GERD's construction without the approval of the downstream countries. Egypt objected to the diversion but to no avail (Salman, 2016).

Egypt asked Ethiopia to discontinue construction until the completion of the NTC-recommended studies. Ethiopia responded that the committee did not ask them to pause the work, claiming no contradiction between the GERD's construction and working on the two studies.

4.2.2.8. The Agreement on Declaration of Principles on the GERD (DoP) (2015)

Conflict over the terms of the NTC studies led to the DoP, signed after much deliberation between Egypt, Sudan, and Ethiopia in Khartoum on 23 March 2015 (Salman, 2018). This was the first agreement in the modern era between these three countries (International Water Law, 2015).

It consists of a preamble and ten principles. Four principles relate to the GERD specifically, while the rest are drawn from international water law principles. The preamble emphasises the value of the Nile for the three countries, and their development, and affirms the basic principle of equality in sharing and using the river among the basin States (Salman, 2018).

Article 1 discusses collaboration, common interests, good faith, international water law principles, and the deep understanding of the water needs of each party (Salman, 2017). Article 2 states the Egyptian and Sudanese recognition of the Ethiopian right in generating sustainable energy by the GERD, which would contribute to the economic development of Ethiopia and regional integration (Salman, 2016). Articles 3 and 4 discuss respectively the two main principles of international water law: the three countries are obligated not to cause any serious damage nor harm to each other; and equality and reasonable utilisation of the Nile's water (International Water Law, 2015).

Article 5 discusses the future recommendations of the International Panel of Experts (IPOE) and its execution regarding the final Technical National Committee (TNC) report. It then states the general rules and guidelines of the first filling of the GERD's reservoir and its operation process. Further, Ethiopia must announce any unpredictable conditions or unexpected circumstances to the downstream countries, if there is a need for a change in the operation of the GERD. The operation of the GERD must be in line with the operation of the rest of the dams owned by the downstream countries. Under Article 6, preference is given to the downstream countries to buy the hydropower generated from the GERD (International Water Law, 2015).

4.2.2.8.1. Subsequent interactions

Even after the signing of this agreement, Egypt has continued to voice strong objections (Salman, 2018) in part due to Ethiopia's continued unilateral actions and rejections of previously agreed terms.

Many meetings have been held between the ministers of water resources and the foreign affairs of the three countries in an attempt to reach an understanding about these studies. The "Khartoum Document" was finally signed by the six ministers on 27–28 December 2015. In this document, Ethiopia agreed to Egypt's request to add two bottom outlets in the dam's body. Yet Ethiopia rejected the Egyptian request in January 2016 (Salman, 2016).

In November 2017, the 17th meeting of the NTC in Cairo ended with no official statement, despite receiving the two long-awaited international reports requested in 2013 The Egyptian minister welcomed the reports,[2] however, Ethiopia and Sudan announced their objection (Salman, 2018). In December 2017, during the Egyptian Foreign Minister's visit to Ethiopia's capital, Addis Ababa, he suggested the technical mediation of the WB. Ethiopia subsequently declined in January 2018 (Salman, 2018).

Throughout, Sudan has worked hard to break the diplomatic impasse. They hosted a tripartite meeting in April 2018., which ended with no results (BuildGreen, 2018). Another tripartite meeting in Cairo, in September 2019, to discuss an Egyptian proposal also ended with a failure to approve (Country report: Sudan, 2019). The Egyptian President met the Ethiopian Prime Minister, in October 2019, during the first Russia-Africa summit in Sochi, to ease the tensions that had arisen between the two sides (Country report: Egypt, 2019).

Article 10 of the DoP allows for mediation in the case of a dispute. At Egypt's request, the USA Secretary of Treasury Steven Mnuchin and a representative from the WB mediated four rounds of talks in Ethiopia (November 2019), Cairo (December 2019) and Washington DC (December 2019). However, Ethiopia withdrew after objecting to the final draft of the agreement presented for signing at the fourth round (Egypt Today, 2019).

On 1 May 2020, Egypt submitted a petition to the UN Security Council asking Ethiopia to respect its obligations and resume talks. The UN Secretary-General urged the three countries to continue the negotiations (UN, 2020).

The Chairperson of the AU brokered further meetings between the leaders of the three countries and the AU Bureau of Heads of State and Government in

[2] These two reports are not publicly available.

June 2020. Trilateral consent to resuming negotiations was agreed upon, along with postponing the filling of the GERD's reservoir until an agreement was reached. From 9 to 17 July 2020, a series of meetings were conducted. Some of the technical issues related to the filling process were agreed upon through these meetings, while some other aspects such as the legally binding status of the agreement were not (TCA Regional News, 2020).

Meanwhile, the Ethiopians started the first fill of the GERD's reservoir in June 2020 (the Ethiopian Prime Minister's office declared on 21 June 2020 that the amount of water required for the first year of the filling had been achieved). Ethiopia declared that this filling was required to test the first two turbines (France 24, 2020). In May 2021, Ethiopia undertook a second filling for the same reason (Endeshaw, 2021) and a third filling in August 2022 (Vincenot, 2022). At the time of writing, negotiations and talks are still ongoing with much tension and no resolution in sight.

4.3. Historical frame interpretation and findings

The contradictory interpretations of the treaties have been seen as a source of great concern to overcome the disputes over the Nile, especially between the downstream and upstream States. No doubt, the persistence of these divergent interpretations presents a challenge to a final resolution of the dispute. Sometimes, these interpretations have dampened disputes, though in most cases they have created uncertainties that fuelled them. Historical interpretations of the Egyptian-Ethiopian conflict have been the main cause of dramatising positions and hampering efforts to end the dispute and establish a stable and peaceful environment, as desired by the international community.

Treaties that were signed during the colonial era directly served the interests of these colonial powers. On the one hand, Ethiopia has made valid and strong arguments to prove that these treaties are not binding. These reasons include:

- These treaties favoured the downstream States to serve the benefits of the colonial powers. There is always a bias presumed where colonial powers sought to pursue their own interests. However, this might have happened accidentally since the colonial powers represented most of the Nile's States at the time.
- These treaties have overridden the existence of some States' territorial sovereignty or domestic jurisdiction. This was one of the results of colonialism and the subjugation of people.
- The upstream States were not included in most of these treaties. Most of these agreements are not comprehensive; instead, they have remained partial, such as bilateral or trilateral agreements.
- One of these treaties was not ratified because of the different interpretations between different language versions. This was one of the main reasons for the dispute.

On the other hand, Egypt has made legitimate claims and arguments to refute the Ethiopian allegations. These include:

- These treaties represent firm evidence of the legitimacy of Egyptian historic rights to the Nile's water. These ancient Egyptian historical rights cannot be overlooked; counterclaims that overlook this reality are futile.

- Throughout history, most of the Nile basin States have not called for their share of water, even after they gained independence. This could be interpreted as their acknowledgement of Egyptian rights, or because they do not need the water.
- Some of the Nile's States were independent free nations when they signed these treaties, so should be committed to their obligations, and be held accountable if they are in breach of them. This includes the legal obligations of signatories to treaties.

After the colonial era, there has been only one bilateral treaty, the 1959 Treaty, which united Egypt and Sudan and separated them from the remaining basin states. The agreement divided the Nile's water amongst the two countries with only a small fraction unallocated and did not take into consideration the rights of the rest of the states, which is considered unfair. Some initiatives were launched later, with no real impact on the legal aspects of the Nile basin States. Thus, the important question of how to share the Nile's water with all relevant States is yet to be answered.

For a long time, Egypt's diplomatic influence played a big role in preventing investment and donations by foreign donors and Western governments to fund the upstream states' water projects, until the Ethiopian government succeeded in gaining investment backing, and started constructing the GERD (Abdulrahman, 2019).

The DoP is the only agreement that relates directly to this dispute. However, this agreement has impacts on Egypt that are harmful rather than beneficial. It provides Ethiopia with Egyptian-Sudanese admission of the GERD, without any documented or binding Ethiopian pledges about the filling processes and operation of the GERD in return. In this way, it legitimises the Ethiopian right but does so without stating or guaranteeing any clear commitments by Ethiopia. The agreement is a general and broad guideline for constructing the GERD that has not accorded much to Egypt. In particular, it has not clarified how Ethiopia will not cause any harm to the downstream States by managing and operating this dam. Later, the USA mediation between the three countries, through a planned four rounds of talks, reached a deadlock because of the Ethiopian withdrawal in the last round.

It can be understood that any proposal related to the use of the Nile that could be offered by one of the Nile basin States will threaten somehow the other states' national interests. That could shed light on the reason that to date, the Nile's treaties have remained partial rather than comprehensive. The significant question regarding how to share the Nile's water has remained unanswered.

4.4. Summary

A historical analytical frame applied in this chapter outlined, explained, and analysed all agreements and treaties conducted over the Nile in chronological order. The frame ends with historical interpretations of these treaties.

As Rotenstreich (1987) states, studying laws may help overcome the fragmentary nature of historical awareness. Thus, the next chapter will use a legal analytical framework to study the legislative and judicial elements of this dispute.

Chapter 5
Legal Perspective

5.1. Introduction

This chapter explicates the legal analytical frame. The analysis starts with an explanation of the international water law principles. Next, these are applied to three similar disputes which they have helped to resolve, and a comparison is made between these and the Egyptian-Ethiopian dispute. The chapter concludes with an evaluation of the GERD dispute from a legal perspective.

5.2. Analysis of the legal analytical frame

International water law and principles are explained and then applied to three similar disputes.

5.2.1. International water law and principles

International water law and principles provide sets of rules and regulations that could clarify "the legality of state actions with respect to water resources" passing through a state's boundaries. They address many aspects related to the uses of transboundary watercourses, such as legal and scientific aspects, and policy issues, and propose different tools and mechanisms to determine the rights and duties of each state, which help in managing watercourses, and solving disputes when they arise (Wouters, 2013).

Security and uses of transboundary water bodies are regulated by many rules set by intergovernmental agreements, which are derived from international law principles (Giordano et al., 2014; Demin, 2015). There is a different set of international rules regarding the navigational and non-navigational uses of international watercourses (Salman, 2007). This study draws on three sets of legal rules and statements regarding the security and uses of transboundary water bodies to analyse the legal situation of the GERD dispute. Salman (2007) classifies three of them as the most important rules regarding the security and uses of transboundary water bodies. These rules are HRs (1966), UNC (1997), and BRs (2004). However, the law is alive and constantly evolving institution. Additionally, these three sets of rules reflect three attempts at different points in time to codify the relevant rules and principles (Salman, 2007).

5.2.1.1. Helsinki Rules (HRs) (1966)

In August 1966, the HRs were issued by the International Law Association (ILA) in Helsinki, Finland (ILA, 1966). These rules are the oldest codification of international water rules (Demin, 2015), covering international rivers and groundwater. The rules constitute 37 articles divided into 6 chapters (ILA, 1966).

Chapter 2 of the HRs discusses the "Equitable utilisation of the waters of an international drainage basin". Article IV, in Chapter 2 of the HRs, asserts the principle of "Equitable and reasonable" utilisation for the waters shared by the members of an international river basin. The factors identifying the equitable and reasonable use of the watercourse determined under Article V are (Demin, 2015):

- The basin's geography, considering the drainage area of each State sharing the basin.
- The basin's hydrology, considering the contribution of water for each State.
- The climate affecting the basin.
- The different dependency on water for each State based on the number of its population.
- The social and economic demands of each basin State.
- The historical and past uses of the waters in the basin, including the current situation of these uses.
- The availability of other water resource alternatives for each State.
- The comparative costs to find water alternatives, which meet the economic and social needs of this State.
- Avoiding the waste in the uses of the water of each basin State.
- The reasonable use of a basin State, which will not cause a "substantial injury" to another basin State.
- The possibility of compensation to one or more basin States, to settle conflicts because of water use (ILA, 1966).

"Complementary Rules Applicable to International Water Resources" were issued in 1986 by the ILA at its Seoul conference to address transboundary groundwater. These rules were the first to discuss how to use, safeguard and manage transboundary aquifers of an international drainage basin. Additionally, more rules were added to these Complementary Rules to clarify the method of dealing with pollution and private remedies in 1996.

The ILA collated all its rules into "The Campione Consolidation of the ILA Rules on International Water Resources, 1966-1999", which was released in 1999 in Campione, Italy (Salman, 2007).

5.2.1.2. United Nation's Convention on the Law of Non-Navigational Uses of International Watercourses (UNC) (1997)

Following a long process of collaboration amongst international legal experts beginning in the 1960s, the International Law Commission (ILC) released the first approved draft of the UN Convention (UNC) in 1991 (Conca et al., 2006). The United Nations General Assembly adopted it in its final form on 21 May 1997 (Carroll, 1999). The final Convention comprised 7 parts and 37 articles, covering general principles for certain rights and obligations for the States in any shared basin (UN, 1997).

- Article (4) clarifies that all States sharing one basin are allowed to join any negotiations, consultations, or agreements that could affect the State, when applied, regarding this entire watercourse.
- The application of the "Equitable and reasonable utilisation and participation" principle among all the basin States was confirmed under Article (5). This should be consistent with suitable protection of the watercourse itself and the interests of the States.
- Article (6) discusses the factors and circumstances that must be considered, while applying the principle of equitable and reasonable utilisation for each State.

- Article (7) explores the principle of “Obligation not to cause significant harm”. This Article indicates that it is not allowed for any State to cause “significant harm” to the other basin States, while discussing the appropriate acts or compensation once the damage is done.
- The concepts of “Sovereign equality, territorial integrity, mutual benefit and good faith” as ground rules for any successful cooperation among the basin States were discussed under Article (8), the “General obligation to cooperate”.
- Articles (9 and 11) emphasise that basin States should exchange information and data regularly and should consult with each other on any expected effects because of “planned measures”, while Article (12) explains what should happen if these “planned measures” are expected to cause a significant negative impact on one or more of the other States.
- The notification process through the basin’s States was discussed under Articles (13, 14, 15 and 16).
- Articles (20, 21 and 23) address ecosystems including the quality of water, and the protection of the marine environment.
- The Convention determines different ways and procedures for dispute settlement under Article (33). It identifies negotiations, mediation or conciliation, arbitration, or appeal to the ICJ, as methods that could be used to help solve disputes in the most peaceful way and identifies the procedures for fact-finding commissions (UN, 1997).

Among the 37 articles, Articles (5) and (7) were the most controversial at the UN convention (Carroll, 1999). The word “harm” in Article (7) is vague and very difficult to identify. The Article discusses the appropriate actions or compensation once the “harm” has occurred to decrease the severity of the consequences but does not show or explain what these actions could be, what kind of compensation could be acceptable, or who judges if the situation requires compensation (Carroll, 1999).

There are many common definitions and factors in the HRs and the UNC. The UNC in effect builds on the HRs by adding further factors for consideration arising from different States’ uses of the watercourse and adds the protection, preservation, improvement, and economic management development of the watercourse resources to the mix. These factors must all be considered together when judging a situation (Salman, 2007).

5.2.1.3. Berlin Rules on water resources (BRs) (2004)

The BRs represent the ILA’s collation and revision of international water law, consolidating and building on the HRs and UNC and including the development of “international environmental law, international human rights law, and the humanitarian law relating to war and armed conflict”. The BRs on Water Resources were approved at the ILA conference held in Berlin in 2004. It includes 14 chapters, divided into 73 Articles (ILA, 2004). In summary:

- The general principles of international law discussing the management of water resources are covered in Chapter II.
- Sustainable management is discussed in the same chapter under Article 7 addressing possible actions to prevent or reduce “environmental harm”.

- In Chapter III, Article 10 confirms that all basin States have the right to equitably, reasonably, and sustainably manage the basin's water.
- The cooperation principle to achieve mutual benefits for the basin States was affirmed under Article 11, based on good faith.
- Article 12 combines the principle of "Equitable and reasonable utilisation" with the "Obligation not to cause significant harm".
- The principle "not to cause significant harm", because of State actions, or omissions while managing the basin's water was again reconfirmed under Article 16, along with the need for "due regard for the right of each basin State to make equitable and reasonable use of the waters".

Commentary on Article 12 confirms that the principle of the "Obligation not to cause significant harm" remains contingent upon the application of the "Equitable and reasonable utilisation" principle. Each State must act responsibly, performing certain duties to achieve an "Equitable and reasonable utilisation", so as not to cause harm to other States.

The BRs illustrate the evolution of the rules over time. The HRs treat the "Obligation not to cause harm" as a factor required to evaluate the "Equitable and reasonable utilisation". The UNC has addressed the "Obligation not to cause significant harm" as a separate Article. However, the Convention uses the same HRs approach of making the "Equitable and reasonable utilisation" serve as the main principle, while treating the principle of the "Obligation not to cause significant harm" as a subordinate principle. BRs treat them equally as both are considered important principles (ILA, 1966; UN, 1997; ILA; 2004). Thus, rather than the rules providing clarity for resolving disputes, they create potentially more sources of conflict as any change in water use is likely to cause harm to at least one party.

5.2.2. The application of international water law to similar disputes

International cases, especially those adjudicated by the ICJ, the main judicial organ of the UN, indicate how water conflicts can be resolved. Fry and Chong (2018) argue that resolutions of the UN Security Council may also hold the legal effect of international water law (Fry & Chong, 2018). The Security Council prevails in the case of a conflict between parties who have adopted the UNC. The Security Council can compel its members to obey its decisions (UN, 1945).

Three similar cases to the GERD dispute have been chosen to explore the application of international law principles: the Gabčíkovo-Nagymaros Dam Project (Hungary/Slovakia); the Botnia UPM Pulp Mills on the River Uruguay (Argentina/Uruguay); the Indus Waters Treaty (IWT) (1960) and the Baglihar Hydroelectric Power Project (BHPP) (India/Pakistan).

5.2.2.1. Gabčíkovo-Nagymaros Project (Hungary/Slovakia)

The Gabčíkovo-Nagymaros Dam project was to construct and operate a large barrage system on the Danube River. In 1977 the Republic of Hungary and Czechoslovakia (now Slovakia) signed the "Budapest Treaty on the Construction and Operation of the Gabčíkovo-Nagymaros Barrage System". This project aimed to establish two series of locks, one at Gabëikovo, in the upstream State (Czechoslovakia) and the other at Nagymaros in the downstream

State (Hungary). Together the locks constituted a "single and indivisible operational system of works" (ICJ, 1997).

Czechoslovakia diverted the Danube's waters, by damming up the Danube at river kilometre 1,851.7 on Czechoslovak territory, which negatively affected the water flow and navigation course for Hungary (ICJ, 1997). In July 1993, both countries requested ICJ adjudication of specific issues arising from the differences that had existed due to the above implementation. They have sought the termination as well of the "Budapest Treaty" that related to this project, and a verdict on the "provisional solution" (ICJ, 1997).

The ICJ was required to adjudicate as to whether Czechoslovakia was "entitled to proceed in November 1991 to the "provisional solution" and to start operating this system from October 1992. The Court was also asked to decide the rights, obligations, and consequences in the case of causing significant harm (ICJ, 1997). The ICJ based its judgement on the UNC, even though the rules were not yet in force (Muhammed, 2005).

The ICJ found that Czechoslovakia's actions violated the Budapest Treaty and Hungarian rights. "It is true that Hungary had agreed to the damming of the Danube and the diversion of its waters into the bypass canal. But it was only in the context of a joint operation and a sharing of its benefits that Hungary had given its consent". It also found that Hungarian suspension or withdrawal from the Treaty constituted a violation of its legal obligations, which indicated its refusal of the joint operation. Nevertheless, it did not mean, "Hungary forfeited its basic right to an equitable and reasonable sharing of the resources of an international watercourse" (ICJ, 1997).

After a year of the Court Judgement in September 1997, Slovakia asked for an additional judgement, because of Hungarian reluctance in executing the Court's first judgement. In its first judgement, the Court asserted the following (ICJ, 1997):

> "Hungary was not entitled to suspend and subsequently abandon, in 1989, the works on the Nagymaros project and on the part of the Gabčíkovo project for which it was responsible, and that Czechoslovakia was entitled to proceed, in November 1991, to the "provisional solution" as described by the terms of the Special Agreement. On the other hand, the Court stated that Czechoslovakia was not entitled to put into operation the barrage system in question. The Court also decided that Hungary and Slovakia must negotiate in good faith in the light of the prevailing situation and must take all necessary measures to ensure the achievement of the objectives of the said Treaty, in accordance with such modalities as they might agree upon. Further, Hungary was to compensate Slovakia for the damage sustained by Czechoslovakia and by Slovakia on account of the suspension and abandonment by Hungary of works for which it was responsible, whereas, again according to the Judgement of the Court, Slovakia was to compensate Hungary for the damage it had sustained on account of the putting into operation of the dam by Czechoslovakia and its maintenance in service by Slovakia.".

Slovakia stated that the two parties had conducted a series of negotiations to implement the ICJ Judgement, and initiated a draft of a Framework Agreement, which was accepted by Slovakia. However, Hungarian approval remained an elusive goal because of a change in the Hungarian government. The two parties resumed the talks later and updated the ICJ on progress (ICJ, 1997).

In June 2017, Slovakia asked the Court to "place on record the discontinuance of the proceedings [instituted by means of the request for an additional Judgement in the case] and . . . direct the removal of the case from the List". Hungary "did not oppose the discontinuance of the proceedings". The Court discontinued the proceedings but noted that both parties reserved their rights to ask the ICJ for further judgements to determine the means of executing its Judgement of September 1997 (ICJ, 1997). Much remains to be done, but hopefully, the dispute is on its way to being settled.

The GERD's situation is very similar to the Gabčíkovo-Nagymaros case, despite the GERD not being a jointly owned or operated project. Egypt, like Hungary, has a signed agreement with Ethiopia setting out the principles of engagement (Helal, 2020) (Articles 1, 3 and 4 of the DoP). The parties agreed not to cause any serious harm to each other, and to equitable and reasonable utilisation of the Nile's flow (Salman, 2016). Ethiopia's freedom to act unilaterally by signing this agreement was constrained, just as that of Czechoslovakia had been in this case (Helal, 2020).

Yet Ethiopia has acted unilaterally in several situations. First, they diverted the Blue Nile to start constructing the dam. Second, Ethiopia has undertaken three stages of filling of the GERD, in June 2020, May 2021, and August 2022 (Alamin & Marks, 2021; Vincenot, 2022). All these actions were taken without any approval of the two downstream States. These unilateral actions placed Ethiopia in a similar position to Czechoslovakia when it diverted the Danube water into its own canal (Youssef et al., 2022).

In the Gabčíkovo-Nagymaros case, the Court held that Czechoslovakia had failed to respect international laws by "unilaterally assuming control of a shared resource, and thereby depriving Hungary of its right to an equitable and reasonable share of the natural resources of the Danube" (Helal, 2020). The ICJ found the action a violation of the "Obligation not to cause significant harm" principle, depriving the other party of its right to an "Equitable and reasonable utilisation" of the watercourse.

Egypt's petition to the UN Security Council following Ethiopia's blatant withdrawal from the USA/WB-mediated talks and unilateral actions in beginning to fill the dam parallels the breakdown in Czech-Hungarian relations and recourse to the ICJ. The UN Secretary-General asked the disputing countries to continue negotiations (Asia News Monitor, 2020). The full statement of Egypt declared that this petition was based on Articles 34 and 35 of the UN Charter. Article 34 gives the Security Council the right to "investigate any dispute or any situation which might lead to international friction or give rise to a dispute, to determine whether the continuance of the dispute or situation is likely to endanger the maintenance of international peace and security". Article 35 gives the members of the UN the right to alert the Council to any situation that might threaten international security and peace (Permanent Representative of Egypt, 2020).

5.2.2.2. Botnia UPM Pulp Mills on the River Uruguay (Argentina/Uruguay)

Argentina made a request on 20 April 2010 to the ICJ to adjudicate its claim against Uruguay that it had acted unilaterally when constructing two pulp mills on the Uruguay River, without prior notification and consultation procedures specified under the February 1975 Argentinian-Uruguayan treaty (the Statute) creating a mutual mechanism for the management and rational utilisation of the Uruguay River. Argentina further claimed the mills would cause environmental damage to the river and its water quality, affecting Argentina negatively. The Court was requested to order Uruguay to suspend works related to these mills pending the final decision, and to abstain from taking any other unilateral actions that could aggravate the dispute.

The ICJ ruled that the Argentinian evidence was not sufficient to grant a provisional halt to construction but confirmed that Uruguay had violated the Statute when failing to report its plans to either Argentina or the Administrative Commission of the River Uruguay (CARU). The Court found no evidence of harmful effects on the water's quality or living species since the beginning of its operations (ICJ, 2010).

Following the ICJ judgement, the Argentinian and Uruguayan presidents held a series of meetings where they agreed to bilateral monitoring of the shared Uruguay River, recorded in "the joint monitoring of the Botnia UPM pulp mills and all the industrial and agricultural establishments and urban centres that discharge their effluents into the Uruguay River and the areas affected by it" signed on 28 July 2010. This agreement also contained provisions for bilateral tools to manage water quality (International Water Law, 2010).

Ethiopia's unilateral action in starting to fill the dam's reservoir in contravention of the DoP agreement appears to parallel Uruguay's action on constructing the mills. Yet while the ICJ's intervention led to negotiations resolving the Argentina-Uruguay dispute, intervention by the UN Security Council and the AU have failed to bring the Egypt-Ethiopia dispute to a conclusion. The difference appears to be Uruguay's willingness to negotiate in good faith to resolve the issue. Ethiopia has not displayed the same willingness to date (Youssef et al., 2022).

5.2.2.3. Indus Waters Treaty (IWT) and the Baglihar Hydroelectric Power Project (BHPP) (India/Pakistan)

For historical reasons, the Indian-Pakistani relationship is complex, full of tension, and largely hostile. The IWT relating to the Indus River, however, appears an exception. After eight years of WB-sponsored negotiations (informed by work of the ILA that led ultimately to the HRs in 1966), India and Pakistan signed the IWT, in September 1960. The Treaty has proved remarkably durable, surviving three subsequent wars between the countries.

A notable feature of the IWT is the effect of the customary international watercourse laws represented in it (Muhammed, 2005). The treaty records India's right to use the waters of the three eastern rivers (the Ravi, Beas, and Sutlej), which carry 33 million acre-feet (maf) of their annual flow to India, and the Pakistani right to use the waters of the three western rivers (the Chenab, Jhelum, and Indus), which provide Pakistan with 165 maf. Close cooperation and information-sharing mechanisms helped in agreeing to the principle of "Equitable and reasonable utilisation". Moreover, under Article III of IWT, upstream state India is forbidden from building storage facilities or storing water on the western rivers, thereby preserving flows to Pakistan. However, India is allowed some limited agricultural use (Annexure C), domestic and non-consumptive use and hydropower generation (Annexure D) (Muhammed, 2005).

In May 1999, India announced its decision to construct the BHPP on the Chenab River in Kashmir. Pakistan's concerns included the design and specifications of the BHPP; disruption and decrease to the flow into Pakistani lands; and the storage area represented by the dam's pondage. On 18 January 2005, Pakistan requested the WB to provide a neutral expert (NE) judgement of India's alleged violation of the NWT, as allowed for in Article IX (2)(a), in proposing the dam (Muhammed, 2005).

The NE report required India to modify the dam's design to lessen its impact on water flow. Specifically:

- The height of the dam (freeboard) should be decreased by 1.5m
- The pondage capacity of the dam should be decreased by 13.5%.
- The specifications of the power intake tunnels should be changed (Khattak, 2008).

Pakistan considered the NE's report a "great victory", as three of their four objections were upheld. However, a fourth objection, requesting a determination on the need for a gated spillway, was not supported.

The IWT provided a framework for effective adjudication and peaceful resolution of the Baglihar project dispute. There are parallels to the GERD case in the dispute itself. The committee of experts' investigation and subsequent report of 25 May 2013, requested by Egypt and Sudan, resembles the BHPP NE's report. It too found design issues with the dam, recommending modifications and further investigations to ascertain downstream effects. However, it has not led to a peaceful resolution. Arguably, this may be due to the lack of a mutually agreed treaty between Ethiopia (upstream) and Egypt and Sudan (downstream) about joint management of the river (paralleling the IWT), separate and distinct from agreements concerning the GERD (the DoP covers the GERD specifically, not other matters of general river management).

5.3. Legal frame discussion and findings

Conflicts over shared watercourses are likely inevitable as the interests of one State invariably take precedence over the interests of other States when decisions are made about water use. The rising demand for freshwater associated with population growth observed currently, and the effects of climate change will likely exacerbate the potential for such conflicts. Many water disputes have been managed through the application of international water law principles, while others have not been successfully resolved.

International water law principles embodied in the HRs and BRs are recommendations, not binding rules (Demin, 2015; ILA, 2004). The UNC is binding only on countries that have adopted it (neither Ethiopia nor Egypt has done so, although this has not prevented the use of its principles in the DoP). However, all three bodies of rules reflect the established principles of customary international laws and carry considerable authority from the experts and international institutions promulgating them (Salman, 2007).

The GERD dispute stems from tensions between the principles of "Equitable and reasonable utilisation" of the Nile's waters and the "Obligation not to cause significant harm".

Ethiopia's position draws upon the principle of "Equitable and reasonable utilisation" and the argument that it has not had its fair share in the past. As an upstream country, it can act unilaterally to access what it deems to be its "fair share", no matter the impact on downstream countries. Egypt draws on the principle of the "Obligation not to cause significant harm" to downstream countries when alleging Ethiopia's unilateral actions are unjust. This obligation defends their current uses and present interests against the expected impacts of upstream countries' new development activities (Carroll, 1999; Salman, 2007).

That Ethiopia is the source of about 84% of the Nile's waters so has the right to a bigger share is not a relevant factor in determining a State's utilisation under the principles (Carroll, 1999), but it could be considered under the hydrological factors (UN, 1997). Ethiopia's high population and comparatively lower per capita income than Egypt's is a social and economic factor that might justify greater use on equity grounds. Ethiopia's use of the GERD to generate electricity to improve economic conditions appears justifiable in this regard. If Egypt's uses of the Nile's water prevent Ethiopia from achieving this objective, then it might be considered inequitable (Carroll, 1999).

Egypt however does rely on "Reasonable utilisation" of the Nile's waters as "Equitable and reasonable" as they have few other sources of water. Egypt requested that the availability of other water alternatives be added during negotiations on the UNC, which is reflected in its Article 6(1). g.) (Carroll, 1999). Egypt, like Ethiopia, has a high population, but its advanced systems ensure conservative usage, another factor for evaluating utilisation, even though it is the largest consumer of the Nile's waters (UN, 1997; Carroll, 1999). Egypt further claims that its historical rights as the first ancient State to use the Nile waters should be taken into consideration in their reasonable usage. Indeed, Ethiopia's historically low utilisation would count against it.

Of the three relevant legal cases reviewed, in each case parties agreeing to a treaty based on international law principles came into conflict when the upstream party acted unilaterally in a manner harming the downstream party. The 'injured' party relied on independent adjudication to resolve the dispute and in each case, the parties have abided by the decisions and recommendations. Yet neither their own actions (independent experts) nor multiple rounds of international adjudication (WB/USA; UN Security Council; AU) have been sufficient to resolve the GERD dispute. Ethiopia continues to take unilateral actions. Egypt retains the option to take the case to international water courts, ICJ, or back to the UN Security Council if satisfactory progress is not made on resolving the dispute.

However, cooperation among disputing States remains the best way to solve any dispute with the least damage for all parties. The two disputing parties need to solve their differences and find common ground via using international water law as a basis while taking into consideration the basic right for humans to have access to clean water at an acceptable cost.

While the UN convention and international water law principles can be used as a realistic starting point for negotiations to help resolve disputes, from the India-Pakistan case, it appears that an agreement about the management of shared watercourses prior to any projects using the water is sound preparation. It may be no coincidence that the historic treaties signed between Egypt and other upstream states have provided such a foundation, enabling (for example) Sudan and Egypt to negotiate several potentially fraught usage cases comparatively amicably, and indeed with shared benefits from later projects (e.g., AHD) being a notable feature.

Moreover, international water law is not only concerned with watercourse usage, shares, or the maintenance of neighbourly relationships, but also with the preservation of ecosystems and marine environments, reduction and control of pollution, protection of species, and protection of the watercourse itself. This scope has been largely ignored during the two states' negotiations; an expanded scope would provide an opportunity for a better solution.

5.4. Summary

This chapter analyses the GERD dispute through the frame of international water law and its application to three similar disputes. This frame and the historic frame in the preceding chapter have provided insights but alone are not enough to reveal the problem's ambiguity. The next chapter uses a risk perspective to assess the situation according to the probabilities and severity of expected risks, and then to compare different decision alternatives under various conditions of risks and uncertainty.

Chapter 6
Risk Perspective

6.1. Introduction

This chapter focuses on frames that highlight the chance or uncertain nature of the situation, namely the Probability and Impact matrix (PIM) and decision-making analytical frames. The PIM frame has been used as a tool to analyse the risks in the case under study. For the decision-making frames, two tools have been used, namely the decision tree and decision table. This chapter provides the analysis and findings of these frames and different tools.

6.2. PIM Risk analysis frame

In this frame, the PIM tool is used to rank and classify the risks as will be explained in the next section.

6.2.1. PIM frame analysis and findings

Data for the PIM frame was collected using interview questions 3-6 from 10 international risk management, water laws, water management and agriculture experts and academics (Appendix A). Questions 3 and 5 related to the likelihood of negative or positive risks for Egypt from the GERD (scale 10%,30%, 50%. 70%, 90%), while 4 and 6 related to the expected impact (scale 5% (very low), 10% (low), 20% (moderate), 40% (high) and 80% (very high)). Participants' responses were collated based on their nationality (European (Eur), upstream countries (UpC), Egyptians (Egy), and Other (Oth) for the balance), as explained in Chapter 3.

The participants' evaluation of the likelihood of the occurrence of the negative and positive risks and their associated impacts on Egypt because of the GERD are summed up in Table 7.

	Threats		Opportunities	
Participant Code	Probability	Impact	Probability	Impact
Eur1	30% (Unlikely)	20% (Medium)	0% (Very unlikely, rare)	5% (Insignificant)
Egy1	50% (Possible)	10% (Low)	0% (Very unlikely, rare)	5% (Insignificant)
Eur2	90% (Almost certain, very likely)	40% (High)	0% (Very unlikely, rare)	5% (Insignificant)
Oth1	90% (Almost certain, very likely)	80% (Very high, catastrophic)	0% (Very unlikely, rare)	5% (Insignificant)
Egy2	90% (Almost certain, very likely)	80% (Very high, catastrophic)	0% (Very unlikely, rare)	5% (Insignificant)

	Threats		Opportunities	
Participant Code	Probability	Impact	Probability	Impact
Eur3	70% (Likely)	80% (Very high, catastrophic)	0% (Very unlikely, rare)	5% (Insignificant)
UpC1	10% (Very unlikely, rare)	10% (Low)	30% (Unlikely)	20% (Medium)
Eur4	30% (Unlikely)	40% (High)	0% (Very unlikely, rare)	5% (Insignificant)
Eur5	50% (Possible)	20% (Medium)	0% (Very unlikely, rare)	5% (Insignificant)
UpC2	10% (Very unlikely, rare)	10% (Low)	50% (Possible)	40% (high)

Table 7: The evaluations that were given by participants.

The results are summarised in Tables 8 and 9.

Probability	Number (%) of participants evaluating threats	Number (%) of participants evaluating opportunities
Prob. ≤ 10% (Very unlikely, rare probability)	2 (20%)	8 (80%)
10% < Prob. < 70% (Unlikely, possible probability)	4 (40%)	2 (20%)
Prob. ≥ 70% (Likely, very likely, almost certain probability)	4 (40%)	0 (No one evaluated the probability of occurrence of opportunities over 70%)

Table 8: The participants' evaluations of the probability in the case of the occurrence of threats and opportunities.

Impact	Number (%) of participants evaluating threats	Number (%) of participants evaluating opportunities
Impact ≤ 5% (Very low, insignificant impact)	0 (No one evaluated the impacts of the threats of the GERD as very low)	8 (80%)

Impact	Number (%) of participants evaluating threats	Number (%) of participants evaluating opportunities
5% < Impact ≤ 10% (Low impact)	3 (30%)	0 (No one evaluated the impacts of the opportunities of the GERD as low)
Impact = 20% (Medium impact)	2 (20%)	1 (10%)
Impact = 40% (High impact)	2 (20%)	1 (10% of participants)
Impact ≥ 80% (Very high, catastrophic)	3 (30%)	0 (No one evaluated the impacts of the opportunities of the GERD as very)

Table 9: The participants' evaluations of the impact in the case of the occurrence of threats and opportunities.

The PIM frame findings

The calculated risk score reflects the criticality of any risk, for both sides, by multiplying the probability by its corresponding impact (equation x).

Total risk score = probability of the occurrence of the opportunities or threats x the corresponding impact of each probability. (x)

Tables 10 and 11 record the results.

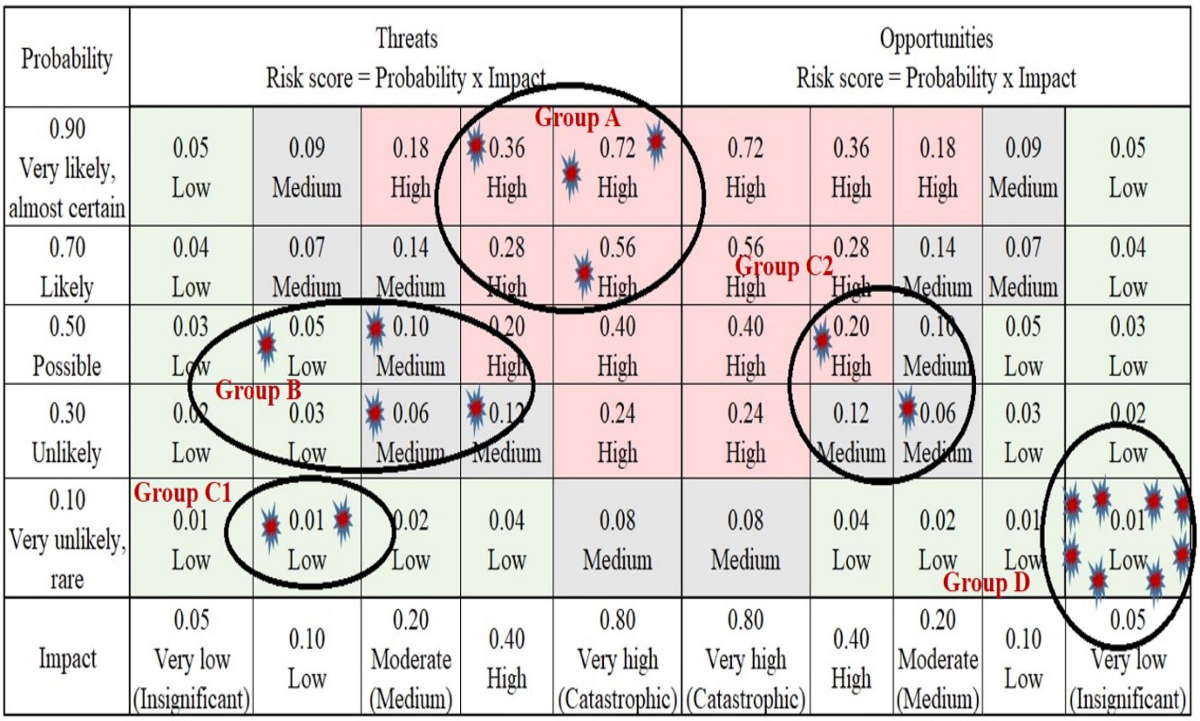
Participant Code	Threats risk score	Threats priorities and criticality	Opportunities risk score	Opportunities priorities and criticality
Eur1	0.06	Medium	0.005	Low
Egy1	0.05	Low	0.005	Low
Eur2	0.36	High	0.005	Low
Oth1	0.72	High	0.005	Low
Egy2	0.72	High	0.005	Low
Eur3	0.56	High	0.005	Low
UpC1	0.01	Low	0.06	Medium
Eur4	0.12	Medium	0.005	Low
Eur5	0.1	Medium	0.005	Low
UpC2	0.01	Low	0.2	High

Table 10: Calculated risk scores for threats and opportunities, their priorities and criticality.

	Number and percentage of participants for each type of risk's criticality	
Risk priorities and criticality	Evaluation of the threats	Evaluation of the opportunities
Low	2 (20%)	8 (80%)
Medium	4 (40%)	1 (10%)
High	4 (40%)	1 (10%)

Table 11: Numbers and percentages of the participants based on their evaluation of the risk priorities and criticality in the case of threats and opportunities.

Figure 12 shows the spread of assigned risk scores on the risk matrix.



Probability	Threats Risk score = Probability x Impact					Opportunities Risk score = Probability x Impact				
0.90 Very likely, almost certain	0.05 Low	0.09 Medium	0.18 High	0.36 High	0.72 High	0.72 High	0.36 High	0.18 High	0.09 Medium	0.05 Low
0.70 Likely	0.04 Low	0.07 Medium	0.14 Medium	0.28 High	0.56 High	0.56 High	0.28 High	0.14 Medium	0.07 Medium	0.04 Low
0.50 Possible	0.03 Low	0.05 Low	0.10 Medium	0.20 High	0.40 High	0.40 High	0.20 High	0.10 Medium	0.05 Low	0.03 Low
0.30 Unlikely	0.02 Low	0.03 Low	0.06 Medium	0.12 Medium	0.24 High	0.24 High	0.12 Medium	0.06 Medium	0.03 Low	0.02 Low
0.10 Very unlikely, rare	0.01 Low	0.01 Low	0.02 Low	0.04 Low	0.08 Medium	0.08 Medium	0.04 Low	0.02 Low	0.01 Low	0.01 Low
Impact	0.05 Very low (Insignificant)	0.10 Low	0.20 Moderate (Medium)	0.40 High	0.80 Very high (Catastrophic)	0.80 Very high (Catastrophic)	0.40 High	0.20 Moderate (Medium)	0.10 Low	0.05 Very low (Insignificant)

Figure 12: The allocation of risk scores on the risk matrix.

The participants were grouped into five clusters, according to their assigned risk scores, to explain the findings. When evaluating the threats expected to happen for Egypt due to the construction of the GERD, three groups became apparent, labelled groups A, B, and C1. Two other groupings emerged when evaluating the opportunities expected to happen for Egypt due to the GERD, labelled C2 and D.

When evaluating the threats expected to happen for Egypt due to the GERD, group "A" represents the 40% of participants who evaluated these threats as high risk regarding its priorities and criticality, with values of 0.36, 0.56, and two for 0.72. This group of participants consisted of four participants as follows: one from Egypt (Egy), two from two different European countries (Eur), and the last one from a country other than the ones mentioned previously (Oth).

For group "B", three of the four participants evaluated the threats as medium risk regarding its priorities and criticality. The risk scores, in this case, were 0.06, 0.10, and 0.12. The three participants were from three other different European countries. While the fourth participant was Egyptian, it appeared that political affiliations played a role in this evaluation. The participant formally has evaluated these threats as low risk regarding its priorities and criticality it was obvious that this participant had some qualms about expressing their view openly as a prominent former official. Hence this participant was included in the medium-risk group.

Group C1 consisted of two participants from the two upstream countries, Sudan, and Ethiopia. Their assessments gave the lowest evaluation of the threats, perhaps not surprisingly given potential bias due to their countries' positions. The risk scores for both were 0.01, which means they evaluated the threats expected to happen for Egypt due to the GERD as low risk regarding its priorities and criticality.

Turning now to the opportunities expected for Egypt due to the GERD, the responses fell into 2 groups, labelled C2 and D. Group C2 consisted of the same two participants from the two stakeholder countries in C1, who evaluated the opportunities as a medium, 0.06, and high, 0.20 regarding its priorities and criticality. However, the rest of the participants, group D, comprising 2 from Egypt and 6 from non-stakeholder countries, evaluated these opportunities as low regarding their priorities and criticality. Some of the participants belonging to group D commented that the expected positive risks that could happen to Egypt have no real impact on the country. Again, the results of group C2 might show a possibility for bias.

Commentary on participants' remarks

A participant from an upstream country (UpC1) explained the threats and opportunities from their point of view. The participant asserted that some of the main **threats for Egypt** would be as follows:

1- The main negative risks will happen during the filling time of the GERD reservoir, especially if the filling time would be concurrent with severe drought (prolonged periods of low rainfall in Ethiopia). During this time, the **Egyptian water flow will be reduced**, which will negatively affect Egyptian agriculture.

2- Filling the dams' reservoirs of the three countries, Egypt, Sudan, and Ethiopia can be extremely challenging because of the **lack of cooperation** among the countries.

3- **No clear or sufficient environmental studies** have been conducted on the GERD effects. Many questions are not yet answered regarding some concerns: the unpredictable consequences and depletion of fisheries; the sustainability of the fish stocks; its impact on resources, ecosystems, and different species; and water quality.

Despite this, the participant has assigned low risk.

Regarding the **opportunities** for Egypt, the participant explained that these opportunities could include the following:

1- The GERD, being in a moderate temperature place, in comparison with the Egyptian dam (AHD), would have a lower evaporation rate in its reservoir. The

coordination between Egypt and Ethiopia to decrease the water storage of the AHD's reservoir and increase the water storage of the GERD's reservoir with its lower evaporation rates will **help in conserving the water** in the Ethiopian highlands, which eventually will help save more water.
2- Egypt can **buy cheap hydropower** from Ethiopia. That could save Egypt a lot of money, in comparison with the costs of electricity generated in Egypt (some studies show that it will be 75% less than the current Egyptian costs). This electricity would be clean, sustainable, and cheap.

The participant also commented on the **Sudanese threats** and opportunities from their view. The participant said that the negative risks for Sudan could be as follows:
1- Vast amounts of **sediment will be trapped behind the GERD**, which will reduce the fertility of the Sudanese soil.
2- There are some concerns regarding the **GERD's safety**. Some studies discussed the negative **impact of the GERD on the Sudanese Roseires reservoir**, which is only 100 km away from the GERD and holds 7.5 bcm of water. That means if anything happens to the GERD, it will affect the Sudanese dam directly.
3- If the **GERD collapsed**, for any reason, **Sudan would literally drown**. The damage would be enormous.

The participant also commented on the **opportunities** for Sudan because of the GERD, saying that Sudan would have the lion's share of the benefits, compared to Egypt) for the following reasons:
1- The Blue Nile is a seasonal river. Its flow is mainly during the rainy season in June, July, August, and early September (75% of its flow is in this period). Sometimes the amount of water during the rainy season could cause catastrophic floods that submerge numerous communities and affect Sudanese farms and infrastructure. The GERD will **regulate the flow of the river** and turn it into a moderate flow (called flattening the hydrograph).
2- After regulating the Nile's flow, Sudan can have more than one agricultural cycle. The Sudanese agricultural cycle is currently limited to the four months of the rainy season. However, with the GERD, **Sudan could grow crops year-round**.
3- Sudan would **increase its electricity capacity** for two reasons. First, **buy cheap electricity** from Ethiopia. Second, Sudan suffers from power outages at different times of the year due to the lack of water flow in the river. The lack of water causes the Sudanese dams' turbines to stop turning to generate electricity. It is expected that the **production of electricity in Sudan's dams could rise by up to 30%** after regulating the water's flow by the GERD.
4- **Navigation** in the river would be improved because of flow regularity.
5- During the flood, the river carries waste, detritus, and sediment, which affects the Sudanese dams. For the **Sudanese Roseires reservoir**, for example, **50%** of the **storage capacity** is filled with **silt**, which reduces the generation of electricity through its turbines. It will not be the case **after the GERD**. This will **reduce the cost of maintenance** of these dams and **increase the production of electricity**.
6- The Blue Nile feeds the Sudanese groundwater in some areas through the flood, but in the drought season, the Blue Nile starts to withdraw this water from the Sudanese groundwater (which is called **reverse withdrawal**). This phenomenon would stop after the GERD, because of the regularity of the flow, which would increase the amount of the Sudanese groundwater.

The participant of the other upstream stakeholder country illustrated that the main **threats for Egypt** will be due to the expected **decrease in water quantity**, which will **affect agriculture, fisheries, and the river's ecosystem**. The participant agreed with the previous participant regarding the expectation of the reduction of evaporation rates, in the case of Egyptian-Ethiopian coordination regarding water storage in the reservoirs of the GERD and the AHD. The participant also agreed about the availability of cheap Ethiopian electricity for Egypt to purchase. The participant suggested that if the two countries succeeded in establishing a **peaceful water cooperation** that would be a beginning of a **new era for the whole region**.

Overall, except for two participants, the results suggest that participants do not see a major possibility of the occurrence of positive opportunities because of the GERD on Egypt. Most of them saw that if there was to be any positive impact it would be insignificant. The only two participants who thought there could be any positive opportunities for Egypt from the GERD were from the other two upstream stakeholder countries. These two countries would have the lion's share of benefits because of the GERD, leading to the potential for bias in their assessments.

On the contrary, the largest block in the group of participants classified the threats to Egypt due to the GERD as high-priority threats, which means they are very important to be dealt with. They evaluated these negative threats as almost certain to happen with catastrophic impact. The second group of participants classified the threats as medium threats, whilst the two participants from the two upstream stakeholder countries were the only two who classified the threats as low. It is worth mentioning that no one classified the impact of these threats as very low. Together these results provide important insights into the determination of the importance and high priority of these threats while showing how insignificant are the opportunities. The analysis also clarifies how serious the problem is. This problem is needed to be studied more to suggest suitable solutions as will be done in the following sections.

It is worth mentioning that Egypt and Ethiopia's location has influenced their relationship, with one at the beginning of the Nile and the other at the end. Fear and mistrust from the Egyptians' side have always dominated Egypt's view regarding what could happen upstream in Ethiopia. For centuries, these feelings have been the norm, not the exception. Hence, the suggestion of cooperation between the two countries made by the previous two participants is seen by many as almost impossible to achieve. The suggestion requires Egyptian acceptance to store more water in the Ethiopian reservoir (GERD's reservoir) than the Egyptian reservoir (AHD's reservoir) because the location of the GERD allows lower evaporation rates than the AHD. Egypt would need to trust Ethiopia to act fairly.

6.3. Decision-making frames

The next sections apply the decision analysis frames by using different tools and different approaches to studying decision-making under two conditions, conditions of risks and conditions of uncertainty as explained below.

6.3.1. The analysis and findings of the decision trees and EV

Question 8 covered the data required for this analysis (Appendix A). The participants were asked to assign payoffs and probabilities for different scenarios by using the anchor points +100 and 0 for payoffs as shown in the next tree.

The participants were asked to evaluate four different Egyptian decision alternatives, which were: negotiate, prepare, do nothing, and war. The first decision was "negotiation", which means the two countries will continue negotiating how they would solve this dispute. The second decision was for Egypt to prepare, which means that Egypt would start to take all measures, actions, and necessary precautions to face the expected shortage in water because of the GERD in all sectors. There was consistency in terms of participants' perceptions of what constitutes preparation for Egypt as they are all experts in related fields. The third is to do nothing, for Egypt just to wait and see. The last decision was war, which means the two countries would take military action.

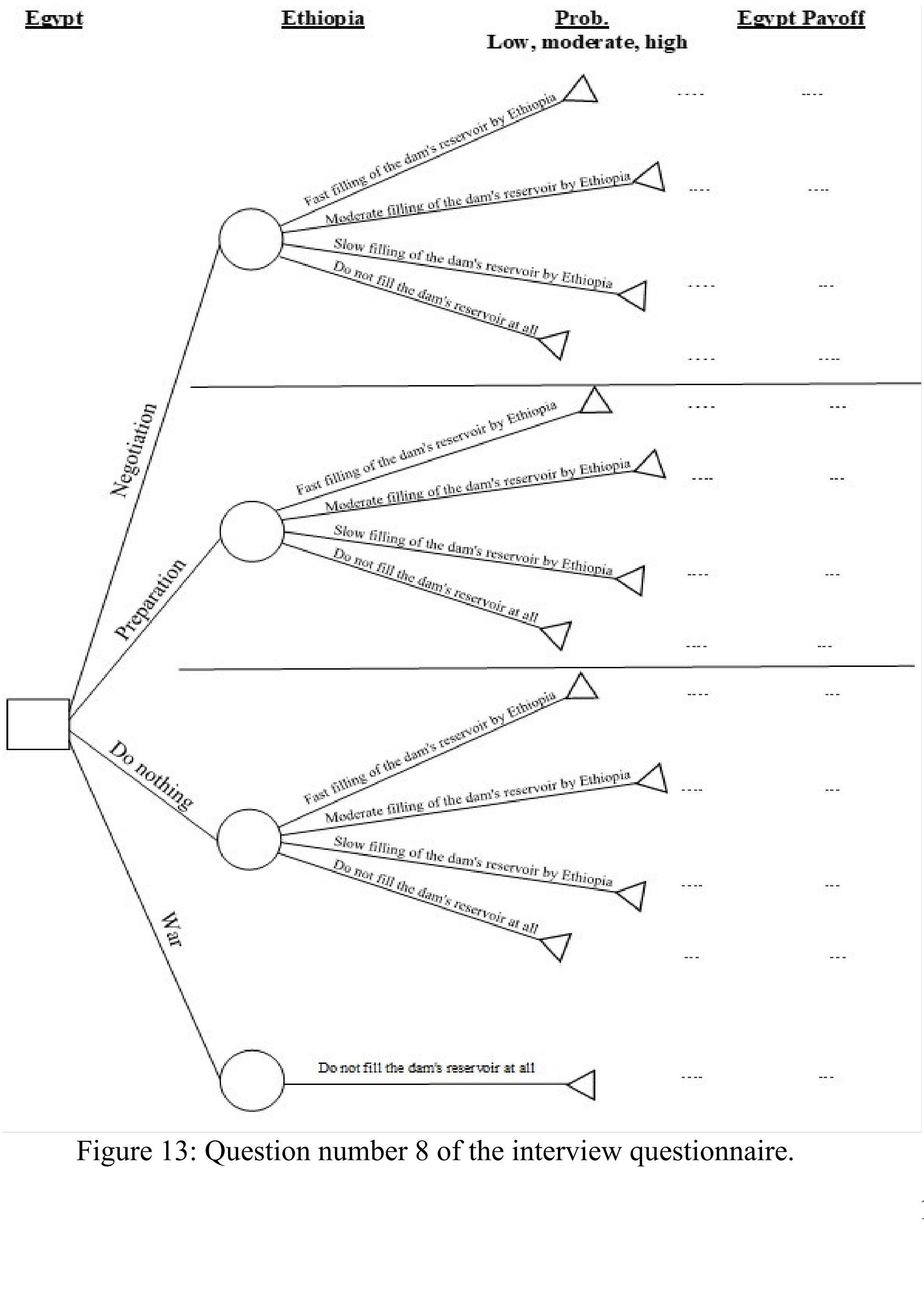


Figure 13: Question number 8 of the interview questionnaire.

The data for the first participant is analysed in detail as an example, while the data analysis for all the participants is followed in aggregated tables.

- Participant Eur1
  The results for participant Eur1 are provided as shown in Figure 14 and Table 12.

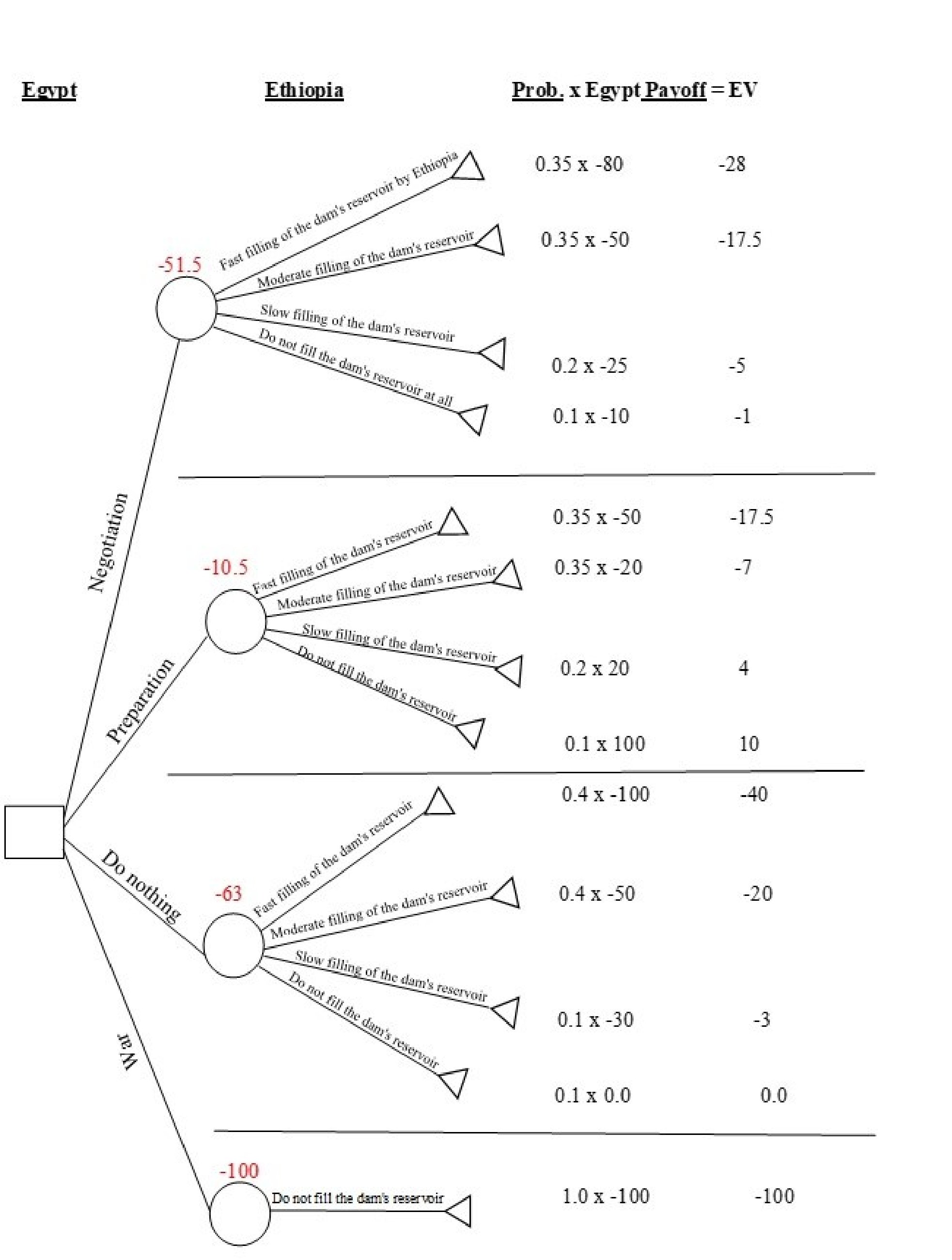


Figure 14: The decision tree for participant Eur1.

The previous tree shows the evaluation of the Egyptian expected payoffs and the corresponding probabilities assigned by participant Eur1 for each decision alternative. Table 12 summarises the values of these payoffs, probabilities, and EV values for participant Eur1.

Egypt's decision alternative for each outcome	Ethiopia	Probability	Payoff	EV
Continue negotiation	Fast filling of the dam's reservoir	0.35	-80	-28
	Moderate filling	0.35	-50	-17.5
	Slow filling	0.2	-25	-5
	Do not fill the dam's reservoir at all	0.1	-10	-1
Prepare	Fast filling	0.35	-50	-17.5
	Moderate filling	0.35	-20	-7
	Slow filling	0.2	20	4
	Do not fill the dam's reservoir at all	0.1	100	10
Do nothing	Fast filling	0.4	-100	-40
	Moderate filling	0.4	-50	-20
	Slow filling	0.1	-30	-3
	Do not fill the dam's reservoir at all	0.1	0	0
War	Do not fill the dam's reservoir at all	1	-100	-100

Table 12: The values of probabilities, payoffs, and EV values for participant Eur1.

The EV value for the first Egyptian decision, which is the negotiation, is -51.5. This is the summation of the values of the four different outcomes for the *Negotiation* scenario (-28, -17.5, -5, and -1). The EV values have been calculated for the 4 decision alternatives. The EV value of the *Prepare* scenario is -10.5, while the EV value of the *Do nothing* scenario is -63. The EV value for the *War* decision is -100. The results for participant Eur1 according to EV criterion show that the best decision alternative to be taken by Egypt is to *Prepare*. That was the highest EV value, which is -10.5. The lowest EV value was -100. That means that this decision alternative is the worst for Egypt, which was the *War* decision.

Commentary on participants' remarks

There were some important points and comments made by participants that need to be mentioned before proceeding with the analysis and findings. It is worth mentioning that all participants, except one, commented on the Ethiopian's outcome of "not to fill the dam's reservoir at all" as an issue that **is not even offered**

for discussion. They considered it completely illogical, except in the case of sparking a war. They all assigned a **zero probability for this outcome**. Even one participant, Eur1, who assigned a probability for this outcome, has assigned a very low probability of 0.1.

Additionally, to evaluate the *War* decision alternative, eight participants assigned its payoff based on the assumption of its occurrence, so they assigned the value 1.00 for its probability. However, they all agreed that the real probability of occurrence of this outcome is almost zero.

Participant Egy2 shared the **pessimism** about the **Ethiopian responses**. The participant said that the future looks bleak when referring to the Ethiopian unilateral actions in the last period in filling the GERD's reservoir as an example; although, Egypt and Sudan objected many times to Ethiopia regarding the matter. This **deadlock** could force Egypt to take risky decisions, and **lead to stand on the brink of war**.

Participant Eur3 questioned if the *Prepare* decision is still available to Egypt, especially since most **affected sectors are inflexible** sectors that need a long time to be able to change their visions, policies, and directions (the agricultural sector for example). The participant commented even if it is still available, **Egypt lacks the investments and the funds** that could turn this decision to be achievable (desalination plants, for example, require a lot of money and at least 3 years to be ready to work).

The participant also commented on the *War* decision that Egypt should be cognisant of the **dangerous consequences** that this would entail, such as: **Ethiopia would divert the Blue Nile** as a punitive action or **sell the water** to other African countries.

The participant expressed concerns due to the **Ethiopian real motive** of constructing the GERD. Although, Ethiopia announced before that it is only for generating electricity, but according to the participant, there is an undeclared intention to use it for agricultural purposes. The participant explained as well that the 'best decision' would vary based on the surrounding circumstances, such as in the case of drought or **'prolonged extended drought'**. In this case, to do nothing would be the only option available to be made by Egypt.

Participant UpC1 **refused all these decision alternatives** and assigned **zero** for the probabilities of all given scenarios and only commented on the war decision. The participant justified that the filling of the dam's reservoir **would not be maintained at the same pace** for the whole time, so the probability of the occurrence of these mentioned scenarios seemed to be non-existent.

UpC1 added that the **deducted portions of the water** to fill the GERD's reservoir would **differ from year to year** depending on the Nile's flow. Therefore, there is no way to tell which scenario would lead to the best payoff for Egypt.

However, UpC1 commented conclusively on the *War* decision that this decision would constitute **major harm with terrible consequences** for both parties. The participant assigned the highest negative value for its payoff.

Turning now to the results of the rest of the participants, Table 13 shows the aggregated values of the probabilities that have been assigned by all participants for each decision alternative.

		Assigned probabilities									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
Continue negotiation	Fast filling of the dam's reservoir	0.35	0.2	0.2	0.2	0.4	0.2	0	0.2	0.2	0.2
	Moderate filling	0.35	0.4	0.4	0.4	0.4	0.4	0	0.4	0.4	0.4
	Slow filling	0.2	0.4	0.4	0.4	0.2	0.4	0	0.4	0.4	0.4
	Do not fill the dam's reservoir at all	0.1	0	0	0	0	0	0	0	0	0
Prepare	Fast filling	0.35	0.2	0.2	0.2	0.4	0.2	0	0.2	0.2	0.2
	Moderate filling	0.35	0.4	0.4	0.4	0.4	0.4	0	0.4	0.4	0.4
	Slow filling	0.2	0.4	0.4	0.4	0.2	0.4	0	0.4	0.4	0.4
	Do not fill the dam’s reservoir at all	0.1	0	0	0	0	0	0	0	0	0

		Assigned probabilities									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
Do nothing	Fast filling	0.4	0.33	0.33	0.33	0.33	0.33	0	0.33	0.33	0.33
	Moderate filling	0.4	0.33	0.33	0.33	0.33	0.33	0	0.33	0.33	0.33
	Slow filling	0.1	0.33	0.33	0.33	0.33	0.33	0	0.33	0.33	0.33
	Do not fill the dam's reservoir at all	0.1	0	0	0	0	0	0	0	0	0
War	Do not fill the dam's reservoir at all	1	1	1	1	1	1	1	1	0	0

Table 13: The aggregated values of probabilities for all participants.

Table 14 shows the aggregated values of the probabilities classified into three categories, low, moderate, and high probabilities. However, the values of participant UpC1 were excluded, because of their refusal of these decision alternatives and assigning zero for all of them.

		Assigned probabilities		
Egypt's decision alternative for each outcome	Ethiopia	Low probability p≤35%	Moderate probability 35<p≤65%	High probability p>65%
Continue negotiation	Fast filling of the dam's reservoir	8	1	0
	Moderate filling	1	8	0
	Slow filling	2	7	0

		Assigned probabilities		
Egypt's decision alternative for each outcome	Ethiopia	Low probability p≤35%	Moderate probability 35<p≤65%	High probability p>65%
	Do not fill the dam's reservoir at all	1	The rest of the participants refused this scenario	
Prepare	Fast filling	8	1	0
	Moderate filling	1	8	0
	Slow filling	2	7	0
	Do not fill the dam's reservoir at all	1	The rest of the participants refused this scenario	
Do nothing	Fast filling	8	1	0
	Moderate filling	8	1	0
	Slow filling	9	0	0
	Do not fill the dam's reservoir at all	1	The rest of the participants refused this scenario	
War	Do not fill the dam's reservoir at all	9	All participants considered this scenario unlikely to happen at all. However, for evaluation purposes, they estimated the Egyptian payoffs in case of its occurrence.	

Table 14: The aggregated values of probabilities classified into three categories.

Table 15 shows the aggregated values of payoffs that have been evaluated by all participants for each decision alternative.

		Evaluated Egyptian payoffs									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
Continue negotiation	Fast filling of the dam's reservoir	-80	-80	-90	-70	-80	-100	0	-100	-80	-70

		Evaluated Egyptian payoffs									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
	Moderate filling	-50	40	20	30	-40	10	0	40	10	40
	Slow filling	-25	70	80	90	-20	70	0	100	90	30
	Do not fill the dam's reservoir at all	-10	0	0	0	0	0	0	0	0	0
Prepare	Fast filling	-50	-70	-40	-50	-10	-50	0	-90	-40	-70
	Moderate filling	-20	50	50	50	30	10	0	20	30	30
	Slow filling	20	80	90	100	60	60	0	80	80	90
	Do not fill the dam's reservoir at all	100	0	0	0	0	0	0	0	0	0
Do nothing	Fast filling	-100	-90	-100	-90	-60	-100	0	-70	-90	-100
	Moderate filling	-50	-50	-70	-60	-40	-80	0	-40	-40	-50
	Slow filling	-30	30	-20	20	-20	-20	0	-20	-20	-20
	Do not fill the dam's reservoir at all	0	0	0	0	0	0	0	0	0	0
War	Do not fill the dam's reservoir at all	-100	-100	-90	-100	-40	-100	-100	-80	-100	-100

Table 15: The aggregated values of payoffs for all participants.

Table 16 shows the aggregated values of EV that have been calculated for all participants for each decision alternative, while the highest and lowest values have been coloured red and green.

		Calculated EV									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
Continue negotiation	Fast filling of the dam's reservoir	-28	-16	-18	-14	-32	-20	0	-20	-16	-14
	Moderate filling	-17.5	16	8	12	-16	4	0	16	4	16
	Slow filling	-5	28	32	36	-4	**28**	0	**40**	**36**	12
	Do not fill the dam's reservoir at all	-1	0	0	0	0	0	0	0	0	0
Prepare	Fast filling	-17.5	-14	-8	-10	-4	-10	0	-18	-8	-14
	Moderate filling	-7	20	20	20	**12**	4	0	8	12	12
	Slow filling	4	**32**	**36**	**40**	**12**	24	0	32	32	**36**
	Do not fill the dam's reservoir at all	**10**	0	0	0	0	0	0	0	0	0
Do nothing	Fast filling	-40	-29.7	-33	-29.7	-19.8	-33	0	-23.1	**-29.7**	**-33**
	Moderate filling	-20	-16.5	-23.1	-19.8	-13.2	-26.4	0	-13.2	-13.2	-16.5
	Slow filling	-3	9.9	-6.6	6.6	-6.6	-6.6	0	-6.6	-6.6	-6.6

		Calculated EV									
Egypt's decision alternative for each outcome	Ethiopia	Eur1	Egy1	Eur2	Oth1	Egy2	Eur3	UpC1	Eur4	Eur5	UpC2
	Do not fill the dam's reservoir at all	0	0	0	0	0	0	0	0	0	0
War	Do not fill the dam's reservoir at all	**-100**	**-100**	**-90**	**-100**	**-40**	**-100**	**-100**	**-80**	0	0

Table 16: The aggregated values of calculated EV for all participants.

Decision trees' findings

Table 17 summarises all EV values for all participants for the four different decision alternatives. The four decisions are put in order starting with the best decision to the worst from the participant's point of view. The table also includes their EV calculated values.

Decisions in order according to their EV value from the best decision to the worst for each participant				
EV value for different decisions	Best decision	Second-best decision	Third-best decision	Worst decision
Eur1	*Preparation* -10.5	*Negotiation* -51.5	*Do nothing* -63	*War* -100
Egy1	*Preparation* 38	*Negotiation* 28	*Do nothing* -56.1	*War* -100
Eur2	*Preparation* 48	*Negotiation* 22	*Do nothing* -71.1	*War* -90
Oth1	*Preparation* 50	*Negotiation* 34	*Do nothing* -56.1	*War* -100
Egy2	*Preparation* 20	*Do nothing* -39.6	*War* -40	*Negotiation* -52
Eur3	*Preparation* 18	*Negotiation* 12	*Do nothing* -66	*War* -100

Decisions in order according to their EV value from the best decision to the worst for each participant				
EV value for different decisions	Best decision	Second-best decision	Third-best decision	Worst decision
UpC1	Scenario was refused	Scenario was refused	Scenario was refused	*War* -100
Eur4	*Negotiation* 36	*Preparation* 22	*Do nothing* -42.9	*War* -80
Eur5	*Preparation* 36	*Negotiation* 24	*War* 0.0	*Do nothing* -49.5
UpC2	*Preparation* 34	*Negotiation* 14	*War* 0.0	*Do nothing* -56.1

Table 17: Decisions in order according to the EV values from the best decision to the worst.

The allocation of number and percentage of participants for different decision alternatives based on the calculated values of EV is shown in Table 18.

Number (%) of participants for each decision alternative based on the calculated values of EV				
The Egyptian decision alternatives	Best decision	Second-Best decision	Third- Best decision	Last decision
Prepare	80% (8 participants)	10% (1 participant)		
Negotiate	10% (1 participant)	70% (7 participants)		10% (1 participant)
Do nothing		10% (1 participant)	60% (6 participants)	20% (2 participants)
War			30% (3 participants)	70% (7 participants)
Refuse all the alternatives	10% (1 participant)	10% (1 participant)	10% (1 participant)	

Table 18: Number and percentage of participants for each decision alternative based on the calculated values of EV.

From these results, we can conclude the following:
Overall, these results indicate that 70% of participants state that the worst and most risky decision that could be made by Egypt is to go to *War* with Ethiopia. Serious concerns were expressed regarding the catastrophic consequences that could happen with this decision, as was discussed through the participants' comments. Another 20% stated that the *War* is not even an available option as a decision

alternative to Egypt; they agree that the worst decision for Egypt is to *Do nothing*. Only one participant, 10%, saw that *Negotiation* could be the worst decision to make when taking into consideration the recent Ethiopian unilateral actions that have been made, which is consistent with the comment from the participant to that effect. As for Egy2, the order of the decision alternatives was *Prepare, Do nothing*, go to *War*, and lastly was *Negotiation*.

The results eliminated the Ethiopian's outcome of 'not filling the dam's reservoir at all by Ethiopia', except in the event of war. Only one participant has considered the idea possible, with a very low probability.

Based on the EV values, 80% of participants saw that the best decision to be made by Egypt was to *Prepare*, while 10% thought that *Negotiation* would be a better decision.

A new decision alternative was suggested by one of the participants from one of the upstream stakeholder countries, UpC1. The participant suggested that the deducted portions of the water to fill the GERD's reservoir would be **distributed differently** from year to year depending on the Nile's flow. That means that the pace of the filling process could vary over the years. According to this idea, the participant had reservations regarding the mentioned scenarios in the question. The participant claimed in this case, there is no way to know which scenarios would better serve Egyptian interests.

One of the aims of this frame was to determine the best and worst decisions to be made by Egypt by considering outcomes arising from possible future Ethiopian actions. From the participants' views, the worst decision for Egypt would be to engage in war. This was followed by the decision of Egypt to *Do nothing*. The best decision for Egypt would be to *Prepare*, followed by continuing with *Negotiation* as the second-best decision.

6.3.2. The analysis and findings of the decision tables

Question 7 covered the data required for this analysis (Appendix A). The participants were asked to evaluate the outcomes for Egypt and Ethiopia by using values between 0 and 100 for the following scenario options, as shown in Table 19. The Ethiopian decision alternatives were reduced from four to two to make sure that interviews would not be too long, and participants would not feel time-pressured, distracted, or exhausted.

	Ethiopia decision	
Egypt decision	Engage in negotiation and fill the dam reservoir at a moderate rate	Refuse to negotiate and fill the dam reservoir at a fast rate
Prepare		
Do nothing		
Negotiate		
War		

Table 19: Question number 7 of the interview questionnaire.

Five different criteria have been used to analyse the data. These criteria as explained before are Maximin criterion, Maximax criterion, Hurwicz's criterion, Laplace's insufficient reason criterion, and Savage's Minimax regret criterion. The data for the first participant is analysed in detail as an example, while the data analysis for the rest of the participants will be followed in aggregated tables.

- Participant Eur1

Participant Eur1	Ethiopia decision					
Egypt decision	Engage in negotiation & fill the dam reservoir at a moderate rate	Refuse to negotiate & fill the dam reservoir at a fast rate	Maximin criterion	Maximax criterion	Laplace's criterion	Hurwicz's criterion
Prepare	100	70	**70**	**100**	**85**	**85**
Do nothing	0	0	0	0	0	0
Negotiate	100	70	**70**	**100**	**85**	**85**
War	0	10	0	10	5	5
The best decision for Egypt in this case from the participant's view is			*Prepare* or *Negotiate*	*Prepare* or *Negotiate*	*Prepare* or *Negotiate*	*Prepare* or *Negotiate*

Table 20: Participant Eur1 evaluation for the payoff table.

The results for the first participant by using the four criteria: Maximin criterion, Maximax criterion, Hurwicz's criterion, and Laplace's criterion are shown in Table 20. For Maximin criterion the least payoff value for each alternative has been determined (70, 0, 70, and 0), and then the alternative that will produce the maximum return will be selected. In this case, two different decision alternatives are equally valued at 70. These two decisions represent the best alternatives for Egypt from the participant's view. These decisions are to *Prepare* or to continue *Negotiating*.

For Maximax criterion the maximum payoff value for each alternative has been determined (100, 0, 100, and 10), and then the alternative that will produce the maximum return will be selected. In this case, two different decision alternatives equally have the same value of 100. These two decisions represent the best alternatives to Egypt from the participant's view. These decisions are to *Prepare* or to continue *Negotiating*.

For Laplace's criterion, the probability of occurrence of each state of nature is assigned the same probability (probability of occurrence = 100% / number of outcomes). In this study, the two Ethiopian decisions represent the state of nature (outcomes). In other words, the probability of occurrence for each of these two decisions is assigned as (1/2 = 0.5). The expected values for the four Egyptian alternatives can be calculated in the following way:
Calculated value of *Prepare* = (1/2)(100) + (1/2)(70) = 85
Calculated value of D*o nothing* = (1/2)(0) + (1/2)(0) = 0.0

Calculated value of *Negotiate* = (1/2)(100) + (1/2)(70) = 85
Calculated value of *War* = (1/2)(0) + (1/2)(10) = 5
The highest value should be selected as the best alternative. In this case, *Prepare* and *Negotiate* have the same highest values, 85.

In this study, the results of Hurwicz's criterion will be the same as Laplace's criterion. The reason behind this similarity is that the assumption of $\alpha = (1-\alpha) = 50\%$. The two Ethiopian decisions have the same opportunity to occur. Therefore, there is no preference. The expected values for the four Egyptian alternatives can be calculated in the following way:
H (Ai) = α (row maximum) + (1 - α) (row minimum)
H *Prepare* = (1/2)(100) + (1/2)(70) = 85
H *Do nothing* = (1/2)(0) + (1/2)(0) = 0.0
H *Negotiate* = (1/2)(100) + (1/2)(70) = 85
H *War* = (1/2)(0) + (1/2)(10) = 5
The highest weighted value should be selected as the best alternative. In this case, *Prepare* and *Negotiate* have the same highest values, 85.

For the last criterion, Minimax regret criterion, the highest payoff that could be received will be assumed to examine the expected regret in each case. For the first Ethiopian decision, engage in negotiation and fill the dam reservoir at a moderate rate, the highest possible payoff is 100. The difference between the highest value and the other values is calculated (0, 100, 0, and 100). The same is applied to the second Ethiopian decision, refusing to negotiate and fill the dam reservoir at a fast rate. The highest possible payoff is 70. The difference between the highest value and the other values will be calculated, (0, 70, 0, and 60). For each decision alternative, the maximum regret value will be chosen, (0, 100, 0, and 100). Then to minimise the regrets, the decision makers should select the minimum of the maximum regrets (0). Therefore, Egypt should decide to *Prepare* or *Negotiate* since both decisions produce the minimum of the maximum regrets, as shown in Table 21.

	Regret table		
Decisions alternatives for Egypt	Engage in negotiation and fill the dam reservoir at a moderate rate	Refuse to negotiate and fill the dam reservoir at a fast rate	Maximum regret
Prepare	0	0	**0**
Do nothing	100	70	100
Negotiate	0	0	**0**
War	100	60	100
Minimax regret decision for Egypt in this case from the participant's view is			Prepare or negotiate

Table 21: Regret table for participant Eur1.

Table 22 provides the results for each participant for all five criteria.

Participant number	Egypt decision	Maximin criterion	Maximax criterion	Laplace's criterion	Hurwicz's criterion	Maximum regret
Eur1	*Prepare*	70	100	85	85	0

Participant number	Egypt decision	Maximin criterion	Maximax criterion	Laplace's criterion	Hurwicz's criterion	Maximum regret
	Do nothing	0	0	0	0	100
	Negotiate	70	100	85	85	0
	War	0	10	5	5	100
Egy1	*Prepare*	90	100	95	95	0
	Do nothing	0	0	0	0	100
	Negotiate	60	100	80	80	30
	War	0	50	25	25	100
Eur2	*Prepare*	60	80	70	70	0
	Do nothing	0	0	0	0	80
	Negotiate	50	80	65	65	10
	War	10	20	15	15	70
Oth1	*Prepare*	80	100	90	90	0
	Do nothing	0	0	0	0	100
	Negotiate	70	90	80	80	10
	War	10	30	20	20	90
Egy2	*Prepare*	80	100	90	90	0
	Do nothing	0	0	0	0	100
	Negotiate	30	90	60	60	50
	War	0	20	10	10	100
Eur3	*Prepare*	60	70	65	65	30
	Do nothing	0	0	0	0	90
	Negotiate	80	90	85	85	0
	War	0	0	0	0	90
UpC1	*Prepare*	70	100	85	85	0
	Do nothing	0	0	0	0	100
	Negotiate	70	80	75	75	20
	War	0	0	0	0	100
Eur4	*Prepare*	20	90	55	55	70
	Do nothing	0	90	45	45	100
	Negotiate	30	100	65	65	60
	War	0	0	0	0	100
Eur5	*Prepare*	30	40	35	35	50
	Do nothing	0	0	0	0	90
	Negotiate	70	90	80	80	0
	War	10	20	15	15	80
UpC2	*Prepare*	20	40	30	30	30
	Do nothing	0	15	7.5	7.5	60
	Negotiate	50	60	55	55	0
	War	0	10	5	5	60

Table 22: The results for each participant for all five criteria.

Commentary on participants' remarks

There were some important points and comments made by participants that need to be mentioned first before proceeding with the findings. Participant Eur1 commented that Egypt should **secretly prepare**. If the Ethiopians know about this preparation, they will consider it as an Egyptian acceptance of the status quo, which would weaken Egypt's negotiating position. Consequently, this would empower Ethiopia to take control over the Nile. Participant Egy1 independently offered the same opinion regarding the Egyptian secret preparation for the same reason.

Participant Oth1 reacted to the decision alternative *Do nothing* by saying that "Egypt cannot take this option right now; Egypt cannot **bear the brunt of such a catastrophic decision**".

Participant Eur3 stated that for some sectors, such as the agricultural sector, there is not enough time for Egypt to make plans and get prepared. He said, "Some of these **sectors are not flexible to be changed** in a short-term period".

Participant Eur4 illustrated that in the case that Ethiopia refused to *Negotiate* and fill the dam reservoir at a fast rate, the costs of preparation would be higher for Egypt than *Do nothing* since Egypt does not have clear information about the amount of water that Ethiopia would allow to flow downstream. The result of the Maximin criterion in Table 22 for participant Eur4 was consistent with this comment. The result shows that to *Prepare* or to *Do nothing* both have 90 points.

Participant Egy2 had some comments, which are listed below:

- The participant criticised the Egyptian acceptance of the **DoP agreement**. The participant said, "It only **made the situation worse**; the agreement has legitimised the GERD's existence without any real benefit to Egypt".
- The participant suggested another decision alternative. This alternative is for Egypt to **urge the UN to back calls for a binding deal** with the Ethiopian party. The participant added that Egypt should call on the UN and different international entities to **intervene or mediate**.
- The participant commented on the *War* decision, "It would be a very **complicated technical decision** for Egypt to take". The participant explained that if Egypt were to attack the GERD, they would need to launch ballistic missiles. These ballistic missiles will travel through other countries' airspace to reach their target. Egypt must gain the permission of these countries. The participant also mentioned that Ethiopia recently bought one of the best air defence systems to protect the GERD. However, the war decision is a **no-win situation** (lose/lose situation). It would be expected in this situation that Ethiopia would fight back.

Decision tables' findings

To sum up, Table 23 presents the best and second-best decisions resulting from using different criteria for each participant, along with its calculated value.

Part. number	Decision	Maximin criterion	Maximax criterion	Laplace criterion	Hurwicz criterion	Minimax regret criterion
Eur1	Best decision	*Prepare* 70	*Prepare* 100	*Prepare* 85	*Prepare* 85	*Prepare* 0
	Second-best decision	*Negotiate* 70	*Negotiate* 100	*Negotiate* 85	*Negotiate* 85	*Negotiate* 0
Egy1	Best decision	*Prepare* 90	*Prepare* 100	*Prepare* 95	*Prepare* 95	*Prepare* 0
	Second-best decision	*Negotiate* 60	*Negotiate* 100	*Negotiate* 80	*Negotiate* 80	*Negotiate* 30
Eur2	Best decision	*Prepare* 60	*Prepare* 80	*Prepare* 70	*Prepare* 70	*Prepare* 0
	Second-best decision	*Negotiate* 50	*Negotiate* 80	*Negotiate* 65	*Negotiate* 65	*Negotiate* 10
Oth1	Best decision	*Prepare* 80	*Prepare* 100	*Prepare* 90	*Prepare* 90	*Prepare* 0
	Second-best decision	*Negotiate* 70	*Negotiate* 90	*Negotiate* 80	*Negotiate* 80	*Negotiate* 10
Egy2	Best decision	*Prepare* 80	*Prepare* 100	*Prepare* 90	*Prepare* 90	*Prepare* 0
	Second-best decision	*Negotiate* 30	*Negotiate* 90	*Negotiate* 60	*Negotiate* 60	*Negotiate* 50
Eur3	Best decision	*Negotiate* 80	*Negotiate* 90	*Negotiate* 85	*Negotiate* 85	*Negotiate* 0
	Second-best decision	*Prepare* 60	*Prepare* 70	*Prepare* 65	*Prepare* 65	*Prepare* 30
UpC1	Best decision	*Prepare* 70	*Prepare* 100	*Prepare* 85	*Prepare* 85	*Prepare* 0

Part. number	Decision	Maximin criterion	Maximax criterion	Laplace criterion	Hurwicz criterion	Minimax regret criterion
	Second-best decision	*Negotiate* 70	*Negotiate* 80	*Negotiate* 75	*Negotiate* 75	*Negotiate* 20
Eur4	Best decision	*Negotiate* 30	*Negotiate* 100	*Negotiate* 65	*Negotiate* 65	*Negotiate* 60
	Second-best decision	*Prepare* 20	*Prepare* or *Do nothing* 90	*Prepare* 55	*Prepare* 55	*Prepare* 70
Eur5	Best decision	*Negotiate* 70	*Negotiate* 90	*Negotiate* 80	*Negotiate* 80	*Negotiate* 0
	Second-best decision	*Prepare* 30	*Prepare* 40	*Prepare* 35	*Prepare* 35	*Prepare* 50
UpC2	Best decision	*Negotiate* 50	*Negotiate* 60	*Negotiate* 55	*Negotiate* 55	*Negotiate* 0
	Second-best decision	*Prepare* 20	*Prepare* 40	*Prepare* 30	*Prepare* 30	*Prepare* 30

Table 23: The results of the participants for the five criteria.

Table 24 displays the number and percentage of participants assigned to the best decision alternatives based on different criteria.

Best decision					
Egypt decision	Maximin criterion	Maximax criterion	Laplace's criterion	Hurwicz's criterion	Maximum regret
Prepare	60% 6 participants	60% 6 participants	60% 6 participants	60% 6 participants	60% 6 participants
Do nothing	0	0	0	0	0
Negotiate	40% 4 participants	40% 4 participants	40% 4 participants	40% 4 participants	40% 4 participants
War	0	0	0	0	0

Table 24: Number and percentage of participants for best decision alternatives.

The number and percentage of participants assigned for the second-best decision alternatives based on using different criteria have been displayed in Table 25.

Second-best decision					
Egypt decision	Maximin criterion	Maximax criterion	Laplace's criterion	Hurwicz's criterion	Maximum regret
Prepare	40% 4 participants	40% 4 participants	40% 4 participants	40% 4 participants	40% 4 participants
Do nothing	0	10% 1 participant	0	0	0
Negotiate	60% 6 participants	60% 6 participants	60% 6 participants	60% 6 participants	60% 6 participants
War	0	0	0	0	0

Table 25: Number of participants for second-best decision alternatives.

- In Table 25, participant Eur4's scores for *Prepare* or *Do nothing* were both equally valued at 90 points for the second-best decision alternatives. That is the reason that the summation of this column came to 110%.
- These results show that the participants can be divided into two groups. The results of the first group show that the *Preparation* decision alternative is their best decision, while *Negotiate* comes second for all five criteria. This group consists of 60% of the total participants. Additionally, it does make sense that the preference of the two Egyptian participants is to *Prepare* as the best decision, which could be considered as giving maximum benefit to Egypt.
- The results of the second group show that the *Negotiate* decision alternative is their best decision, while *Prepare* comes second. This group consists of 40% of the participants. This included the Ethiopian participant, for whom the preference for Egypt to *Negotiate* is understandable from their country's perspective.
- These results also suggest that all participants saw that the other two decision alternatives, to *Do nothing* and start a *War*, are not acceptable decisions. These two decisions had often proved costly in the long term according to the participants' views. These results are echoed conclusively in the regret tables, with these two decision options scoring the highest values as a regret indicator.
- There were some suggestions that there is no contradiction between the two other decision alternatives, *Prepar*e and *Negotiate*. On the contrary, some participants questioned if these scenarios could be applied together.
- Some participants expressed concerns regarding the extremely short time available to Egypt to get prepared. Some even went as far as to talk about the losses that could occur for some sectors, which are not flexible to change such as agriculture.
- What emerges categorically from the results reported here is that all participants recommended that the best and second-best decisions to be taken by Egypt are *Prepare* and *Negotiate*.
- These results conclude two new scenarios. The first is the combination of preparation and negotiation. This new scenario for Egypt is to prepare for this serious situation, while continuing the negotiations with Ethiopia. The second is that Egypt should call on the UN and different international entities to intervene or mediate and to urge the UN to back calls for a binding deal with Ethiopia.

- These results comply with the findings that have been concluded by using the previous tool, decision trees, where *Prepare* comes as the best decision, while *Negotiate* comes as the second-best decision.

  Based on the findings of using the last two tools, decision trees and tables, **three new scenarios have emerged** that might better serve the Egyptian interests if they could be applied.

  1. The first scenario comes from applying two decisions together. These decision alternatives are to *Prepare* and *Negotiate* at the same time. No contradiction or conflict arises in applying them in conjunction. However, ideally, the Egyptian's preparation is done quietly and discreetly so as not to affect the Egyptian position during negotiations.

  2. The second scenario is that the filling of the GERD's reservoir should be paced in such a way as to cause minimal disruption or even benefit downstream states. The deducted portions of the water could be increased through the flood seasons, and decreased through the drought seasons, while it could be paused through a prolonged extended drought.

  3. The third scenario is for Egypt to call on the UN and different international entities to intervene or mediate and to urge the UN to back calls for a binding deal with the Ethiopian party.

  In this study, the decision-making analytical frame fully played its role. Based on the previous results, the frame helped in exploring all aspects of the heated Egyptian-Ethiopian dispute, while taking into consideration the scenarios that have not yet happened. It created new decision alternatives for exploring new paths for the future. This might help decision makers to develop long-term strategic plans based on these results. However, to provide solution(s) for this situation and delve deeper into cause-effect relationships, the researcher will use TOC in the next chapter to cover new aspects of the study.

6.4. Summary

The analysis and findings of the PIM and decision-making analytical frames were provided in this chapter. The PIM was used to analyse the risks in the case study. Decision trees and tables were used to structure and analyse the effects of different decision alternatives, while different methods and approaches were used to analyse the data. The results of the analysis suggested that Egypt should prepare to meet the changes caused by the GERD's existence and operation, as well as continue negotiations with Ethiopia. The analysis also prompted the development of three new actions (numbered above) that Egypt could consider.

However, these frameworks have neither provided a solution for the conflict nor assisted in identifying the causes and undesirable effects of the problems. Therefore, the TOC analytical frames are used next to provide a detailed and rigorous analysis of these aspects to complement the former frames, and to develop solutions for this critical situation.

Chapter 7
Theory of Constraints Perspective

7.1. Introduction

This chapter adopts a Theory of Constraints (TOC) perspective by applying TOC Thinking Processes (TPs) tools and TOC 5 Focusing Steps (5FS). Five different TP tools are used, each for a different purpose, to analyse the situation, diagnose the root causes of the situation facing Egypt, and develop solutions and implementation plans. The TP tools used are the Goal Tree (GT), Current Reality Tree (CRT), Evaporating Cloud (EC), Future Reality Tree (FRT), and Prerequisite Tree (PRT). This chapter provides the analysis, diagrams, and findings.

7.2. TOC analysis and findings

The TOC analysis started with two logic trees, the GT and CRT, followed by the EC analyses, two further logic trees (FRT and PRT) and lastly the TOC 5FS analysis. It is worth mentioning that data used for different frames in this chapter was collected using interviews with Egyptian participants. The entities of the trees came from participants' comments. These views differed based on the category that these participants belong to as will be explained later. The researcher aimed to represent their voices as accurately as possible with transliteration and minimal editing.

7.2.1. Goal Tree analysis and findings

Data for the GT frame was collected using interview questions 4-7 (Appendix A), which asked the participants to identify the agricultural sector's goal(s), Critical Success Factors (CSFs), and Necessary Conditions (NCs), and if any of these NCs were met. These questions were as follows:

4) Thinking about the agriculture sector in Egypt, do you think any changes are needed?
5) What would you say is the goal(s) of the agriculture sector and the CSFs necessary for achieving that goal(s)?
6) What would you say is the goal(s) of your own work and the CSFs necessary for achieving that goal(s)?
7) What are the NCs required to satisfy the important/ CSFs you just identified?
a. Which (if any) of these NCs are not being met now?
b. What about when the dam starts operating?

Based on the participants' answers, the GT was created to answer the first question "Why change?". Any GT starts with the bigger strategic goal of the system at the top of the tree. The CSFs come below this goal, then the NCs are below CSFs. These NCs are the conditions that are needed to make it possible. The GT sought to show what the Egyptian agricultural sector's goals would look like. The participants also identified which of these NCs have not been met until now. If there is no evidence of the NCs existing, then it is unlikely that the CSFs or goals will be met.

The participants' answers revealed one main goal with many sub-goals. After consolidating multiple inputs that said essentially the same thing, a clearly articulated goal, CSF, and NC factors were organised into vertical relationships among levels of objectives. The GT could be seen as a nested hierarchy of goals, CSFs, and NCs. Moreover, the CSFs, or NCs at a higher level sometimes acted as a goal of a lower level and vice versa. To explain the analysis in detail, the GT has been divided into subordinate GTs that show the vertical dependencies of the studied system.

The goal that emerged at the highest level encapsulated the national goals expressed by participants. It was clear that the main goal was Egypt's survival, which most of the participants clarified: that the Nile's water is a matter of life or death to Egypt as represented in GT 1.

The first level of CSFs identified by participants to achieve the main goal of "Ensure Egypt's survival" were:
- Human well-being
- Successful economy
- Improved performance of the Egyptian agricultural sector

Moreover, the NCs to achieve these CSFs have been identified as:
- Maintain employment levels to have a successful economy and human well-being.
- Adequate food production (to supply people's needs and exports) to have a successful economy.

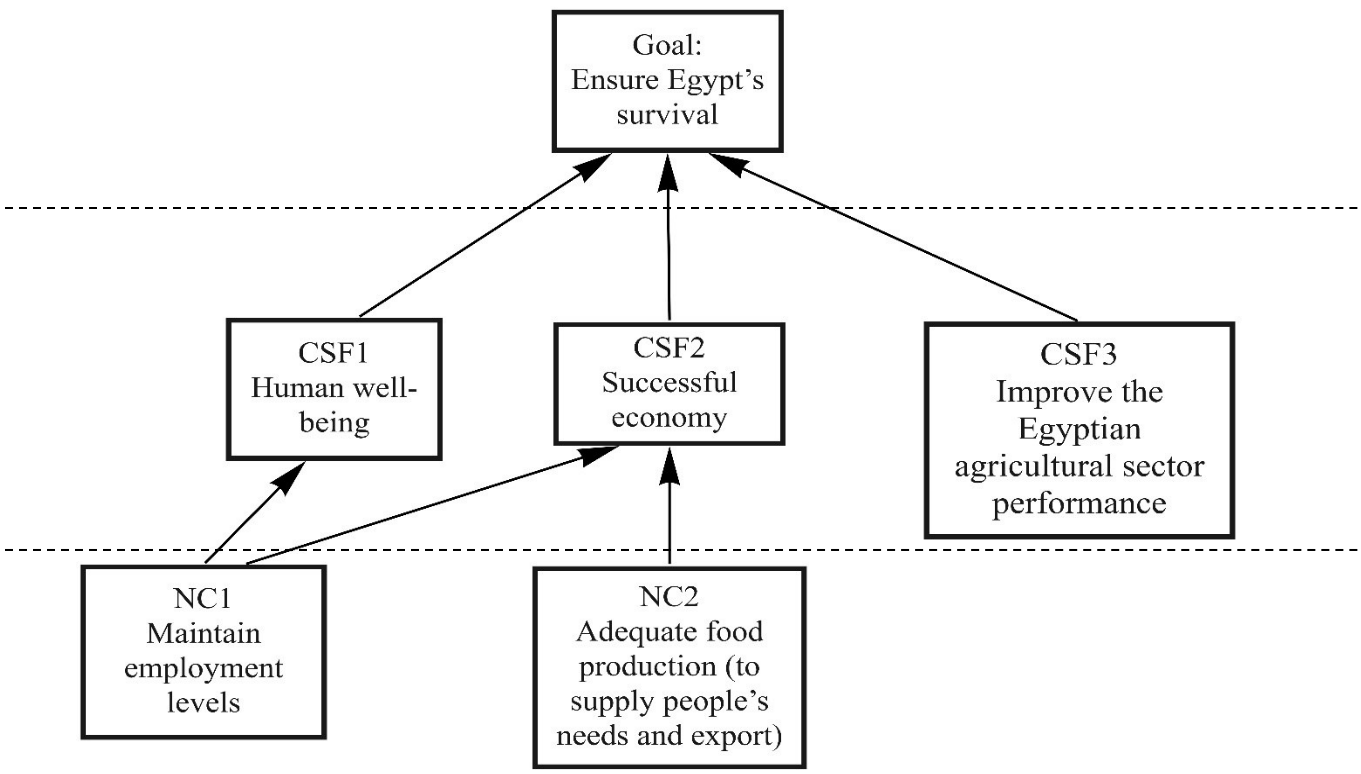


Figure 15: Goal Tree Level 1 (GT 1)- Goal: Ensure Egypt's survival.

At the next level down, GT 2 represents the CSFs and NCs for CSF3 in GT 1, the improved performance of the Egyptian agricultural sector, which is the focus of this research. Four CSFs were seen to be necessary to enhance the performance of the Egyptian agricultural sector as shown in Figure 16. The four CSFs covered efficient and effective agricultural and water management practices, maximising the productivity of the water and land units, and effective governmental agricultural policy framework.

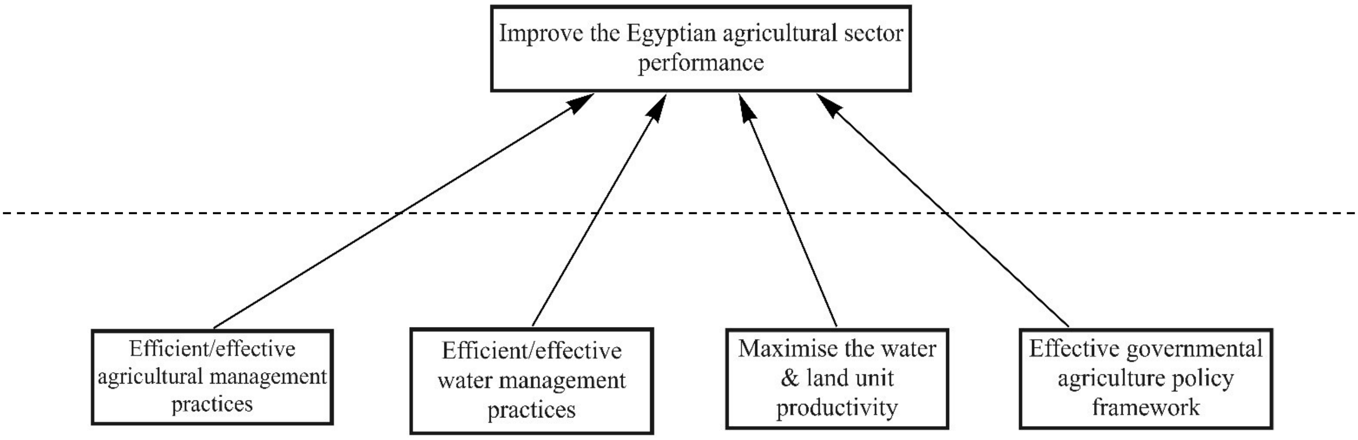


Figure 16: Goal Tree Level 2 (GT 2)- Goal: Improve the Egyptian agricultural sector performance.

There are four subordinate GTs for the CSFs in GT2, as shown in GTs 2.1, 2.2, 2.3, and 2.4. GT 2.1 works on "efficient/effective agricultural management practices" as the main goal for the tree and determines the CSFs, and NCs for its success.

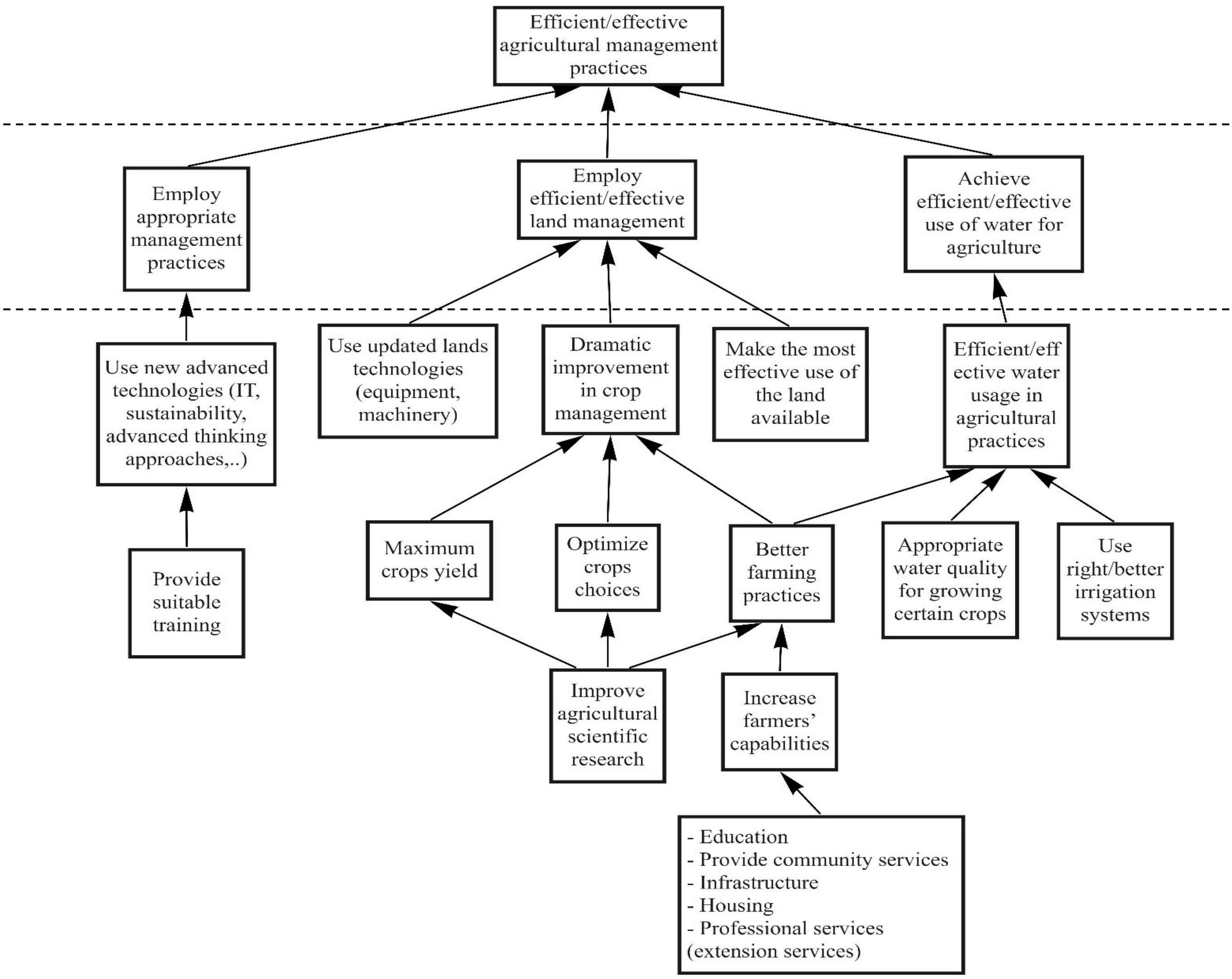


Figure 17: Goal Tree Level 3 (GT 2.1)- Goal: Efficient/effective agricultural management practices.

For GT 2.2, "efficient/effective water management practices" acts as the goal while the CSFs, and NCs were determined in order to achieve this goal, as shown in Figure 18.

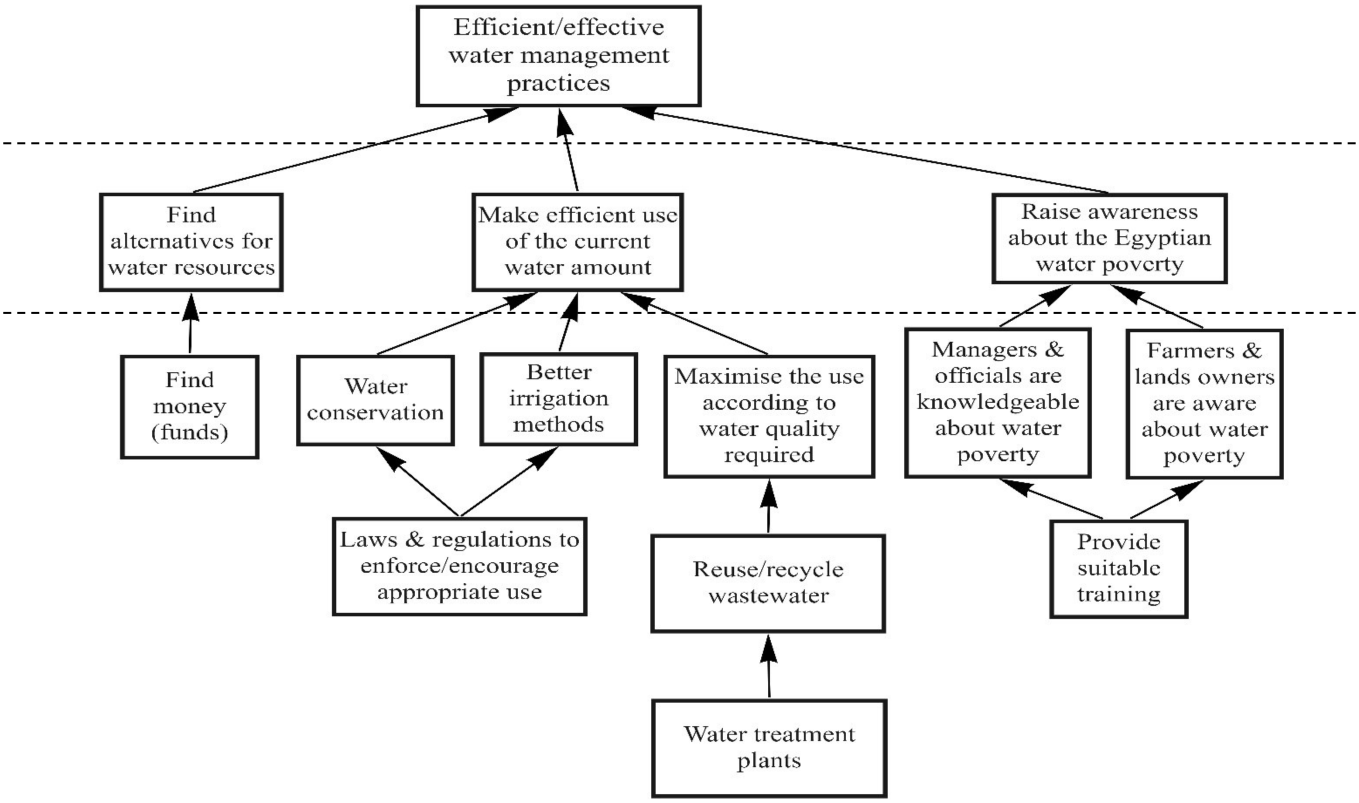


Figure 18: Goal Tree Level 3 (GT 2.2)- Goal: Efficient/effective water management practices.

In order to "maximise the water and land unit productivity", the CSFs, and NCs were determined based on the participants' answers, as shown in GT 2.3.

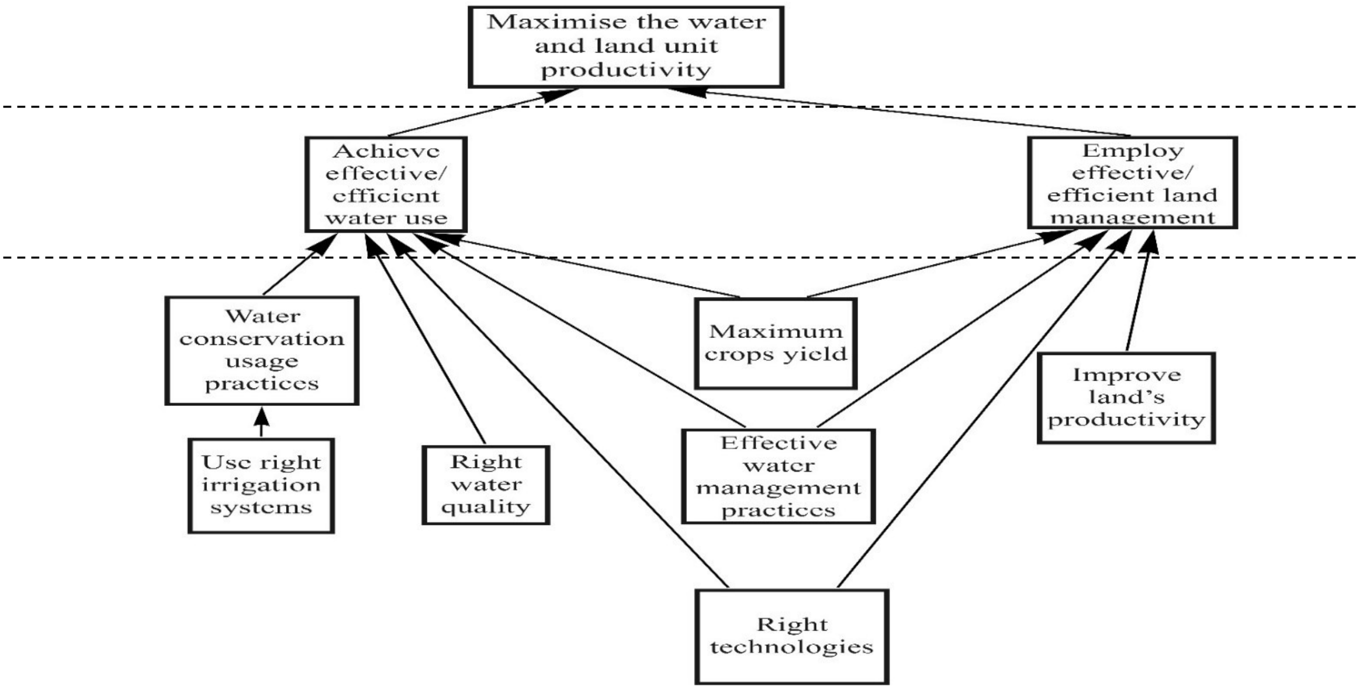


Figure 19: Goal Tree Level 3 (GT 2.3)- Goal: Maximise the water and land unit productivity.

Lastly, for "Effective governmental agricultural policy framework", the CSFs, and NCs are shown in Figure 20: GT 2.4

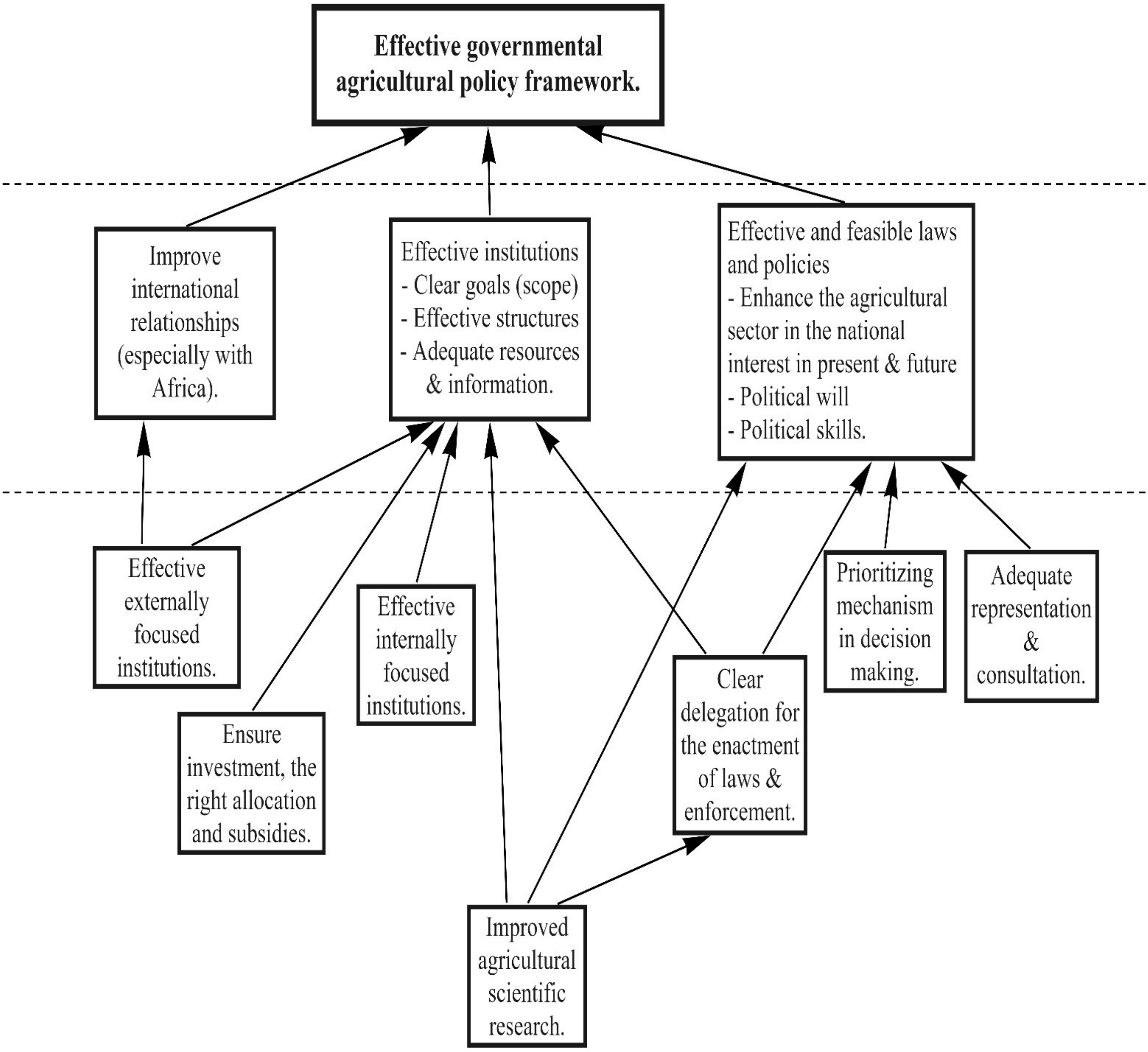


Figure 20: Goal Tree Level 3 (GT 2.4)- Goal: Effective governmental agricultural policy framework.

It could be noticed that the NCs become progressively more detailed, specific, and functional as one descends.

The subordinate GT 3 represents the CSFs and NCs for NC 1 in GT 1, maintain employment levels, which is closely related to agriculture as one of the labour-intensive sectors, as was explained in Chapter 2.

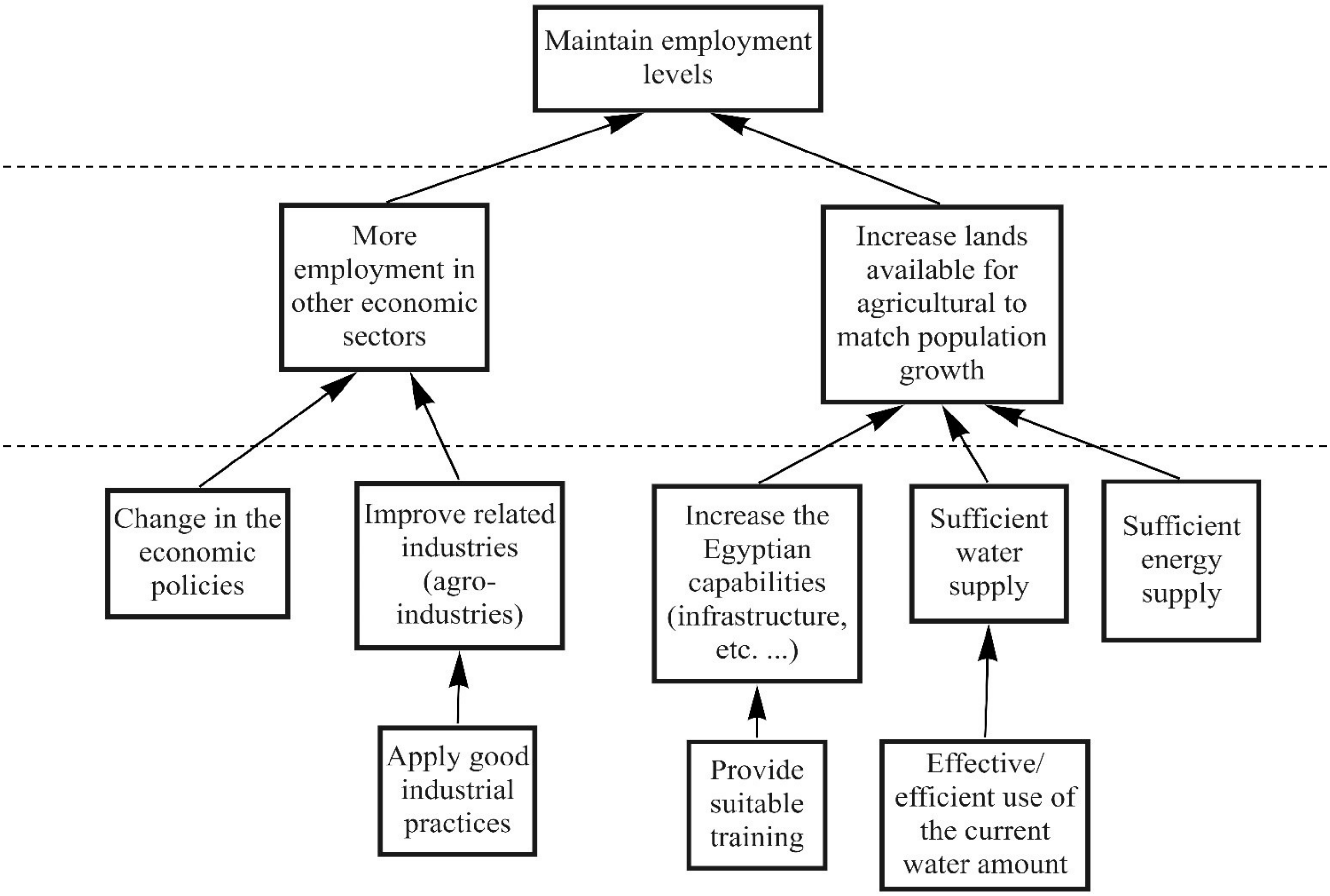


Figure 21: Goal Tree Level 3 (GT 3)- Goal: Maintain employment levels.

<u>*Commentary on participants' remarks*</u>

Most participants commented that the CSFs and NCs have not been achieved at all. A few participants clarified that while some are a 'work in progress', they are being done neither effectively nor fast. Therefore, it is unlikely that the goals will be met under the current circumstances. Moreover, they expected that the situation will get much worse rapidly after the GERD starts operating especially since Egypt already suffers from water poverty. They added that the worst period would be during the reservoir filling and drought seasons. However, some participants expected that the agricultural sector would fully collapse, unless there is a rapid implementation of the required changes, especially if the pace and extent of implementation remain inadequate.

Some illuminating comments made by participants are provided below and are ordered according to the category the participant belongs to. It starts with participants belonging to NL, then LL, and finally IL. The same technique is used with all the TOCs tools when presenting the participants' comments.

Participant NL1 claimed that an **Egyptian economic shift** is necessary right now. The participant pointed out that the Egyptian agricultural sector will not be able to stand against the expected decrease in water. It was one of the comments that helped in shaping CSF 1 of GT 3, "more employment in other economic sectors", which in turn helped in articulating its NCs.

Participant NL4 reported that the agricultural sector is one of the most important sectors in the whole world. The participant said, "The total area of lands that have been reclaimed in Egypt in the last 30 years exceeds 3 million acres,[3] which represents more than half of the area of the Nile Valley and the Delta (the old lands). Egypt has highly experienced experts and professionals in this field."

Participant NL5/IL1 deplored the high rate of losses incurred by Egyptian agricultural production, saying "It reaches 30% of the total production and is considered one of the highest rates of agricultural losses in the world." He explained that there are different reasons behind these losses, such as storing, harvesting, milling or the cold chain, or during the loading of trucks. (The cold chain comprises the actions and equipment that are required to maintain agricultural products within a low temperature from harvest to consumption.) He also recommended applying the concept of the culture and agricultural value chain in the agricultural sector, especially investing in the cold chain phase from the fields until reaching the distributors and customers. He added, "**Culture Value Chain** is a proven formula where a strong corporate culture and employee engagement equate to the ability to innovate, achieve higher customer satisfaction, and ultimately deliver stronger financial performance".

He also defined the **agricultural value chain** as "The people and activities that bring a basic agricultural product, like maize, vegetables, or cotton, to the consumers: all the way from obtaining inputs, and production in the field, through different stages such as processing, packaging, and distribution, till they reach consumers. Agricultural value chains encompass the flow of products, knowledge and information between smallholder farmers and consumers. They offer the opportunity to capture added value at each stage of the production, marketing, and consumption process". These comments, among others, led to form CSF 1 at GT 2-1, whose subordinate goal was "efficient/effective agricultural management practices." The CSF 1 was to employ appropriate management practices.

One of the new advanced technologies suggested by participant IL5 was **hoop houses**. The participant explained, "hoop houses are constructed from a tubular steel frame covered by plastic. It is a type of solar greenhouse in which crops grow directly in the soil but they are sheltered by the structure. A hoop house is relatively inexpensive to buy and operate because it has no artificial lighting or temperature controls." "Use new advanced technologies" was NC 1 in GT 2-1 responsible for the previous subordinate goal.

Participant LL5/IL8 claimed that one of the factors that reduces the productivity of Egyptian lands is the **fragmentation of land holdings**. The participant illustrated that the two reasons behind the fragmentation issue are: first, the **land reform law** in Egypt issued in September 1952 which prohibited landowners from possessing more than 200 feddans[4] of land, and second, splitting the inheritance after the death of a land holder/owner.

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[3] Acre is a unit of land measurement. One acre is equivalent to 0.4047 hectare or 4,047 square metres.

[4] Feddan is a unit of land measurement used in Egypt and some Arabic countries. One feddan is equivalent to 4,200 square metres.

The participant argued that the continuous subdivision of farms leads to small-sized lands that may be hard to economically operate or effectively produce the results expected and required. This leads to inefficient production due to the inability to use modern irrigation methods, or apply an agricultural strategic national plan in such small-sized lands. This eventually affects the overall Egyptian exports and wastes huge quantities of water.

The fragmentation of land holdings issue was included in CSF 3 of GT 2-4. This GT discussed the "effective governmental agricultural policy framework" and this CSF was related to the "effective and feasible laws and policies."

The participant also expected that climate change will have huge impacts on the whole region, represented by a decrease in water flow and levels, land subsidence and sinkhole formation in some areas caused by the expected heavy withdrawal of groundwater.

The findings of the GT

Table 26 summarises the goals, CSFs, and lower levels of supporting NCs of the Egyptian agricultural sector to answer the question "Why change?"

GT Code	Goal	CSFs	NCs
GT 1	Ensure Egypt's survival.	1- Human well-being.	1- Maintain employment levels in order to have a successful economy and human well-being.
		2- Successful economy.	1- Maintain employment levels in order to have a successful economy and human well-being. 2- Adequate food production (to supply people's needs and export) in order to have a successful economy.
		3- Improve the Egyptian agriculture performance.	
GT 2	Improve the Egyptian agriculture sector performance.	1- Efficient/effective agriculture management practices. 2- Efficient/effective water management practices. 3- Maximise the water & land unit productivity. 4- Effective governmental agriculture policy framework.	
GT 2-1	Efficient/ effective agriculture	1- Employ appropriate management practices.	1- Use new advanced technologies (IT, sustainability, advanced thinking approaches, etc.). 1-1 Provide suitable training.

GT Code	Goal	CSFs	NCs
	management practices.	2- Employ efficient/effective land management	1- Use updated land technologies (equipment, machinery). 2- Dramatic improvement in crop management. 3- Make the most effective use of the land available. 2-1 Maximum crops yield. 2-2 Optimise crop choices. 2-3 Better farming practices. 2-1-1 & 2-2-1 & 2-3-1 Improve agriculture scientific research. 2-3-2 Increase farmers' capabilities. 2-3-2-1 Education, provide community services, infrastructure, housing, and professional services (extension services).
		3- Achieve efficient/effective use of water for agriculture.	1- Efficient/effective water usage in agriculture practices. 1-1 Better farming practices. 1-1-1 Increase farmers' capabilities. 1-1-1-1 Education, provide community services, infrastructure, housing, and professional services (extension services). 1-2 Appropriate water quality for growing certain crops. 1-3 Use right/better irrigation systems.
GT 2-2	Efficient/ effective water management practices.	1- Find alternatives for water resources.	1- Find money (funds).
		2- Make efficient use of the current water amount.	1- Water conservation. 2- Better irrigation methods. 1-1 & 2-1 Laws & regulations to enforce/encourage appropriate use. 3- Maximise the use according to the water quality required. 3-1 Reuse/recycle wastewater. 3-2 Water treatment plants.
		3- Raise awareness about the Egyptian water poverty.	1- Managers & officials are knowledgeable about water poverty. 2- Farmers and landowners are aware of water poverty. 1-1 & 2-1 Provide suitable training.
GT 2-3	Maximise the water & land unit productivity.	1- Achieve effective/ efficient water use.	1- Water conservation usage practices. 1-1 Use right irrigation systems. 2- Right water quality. 3- Right technologies. 4- Effective water management practices. 5- Maximum crops yield.
		2- Employ effective/ efficient land management.	1- Improve land productivity. 2- Right technologies. 3- Effective water management practices. 4- Maximum crops yield.

GT Code	Goal	CSFs	NCs
GT 2-4	Effective governmental agriculture policy framework.	1- Improve international relationships (especially with Africa).	1- Effective externally focused institutions.
		2- Effective institutions - Clear goals (scope). - Effective structures. - Adequate resources & information.	1- Effective externally focused institutions. 2- Ensure investment, the right allocation, and subsidies. 3- Effective internally focused institutions. 4- Improve agriculture scientific research. 5- Clear delegation for the enactment of laws & enforcement. 5-1 Improve agriculture scientific research.
		3- Effective and feasible laws & policies - Enhance the agriculture sector in the national interest in present & future. - Political will. - Political skills.	1- Improve agriculture scientific research. 2- Clear delegation for the enactment of laws & enforcement. 2-1 Improve agriculture scientific research. 3- Prioritizing mechanism in decision making. 4- Adequate representation & consultation.
GT 3	Maintain employment levels.	1- More employment in other economic sectors.	1- Change in the economic policies. 2- Improve related industries (agro-industry). 2-1 Apply good industrial practices.
		2- Increase lands available for agriculture to match population growth.	1- Increase Egyptian capabilities (infrastructure, etc.). 1-1 Provide suitable training. 2- Sufficient water supply. 2-1 Effective/ efficient use of the current water amount. 3- Sufficient energy supply.

Table 26: The summation of the goals, CSFs, and NCs for the complete GT.

The complete GT, shown in Figure 22, represents the different vertical and horizontal relationships among its various levels of objectives in a nested hierarchy of goals, subordinate goals, CSFs, and NCs. Some of these CSFs and NCs at a higher-level act as a goal at a lower level. The complete GT diagram is segmented based on the subordinated GTs as can be seen in Figure 22.

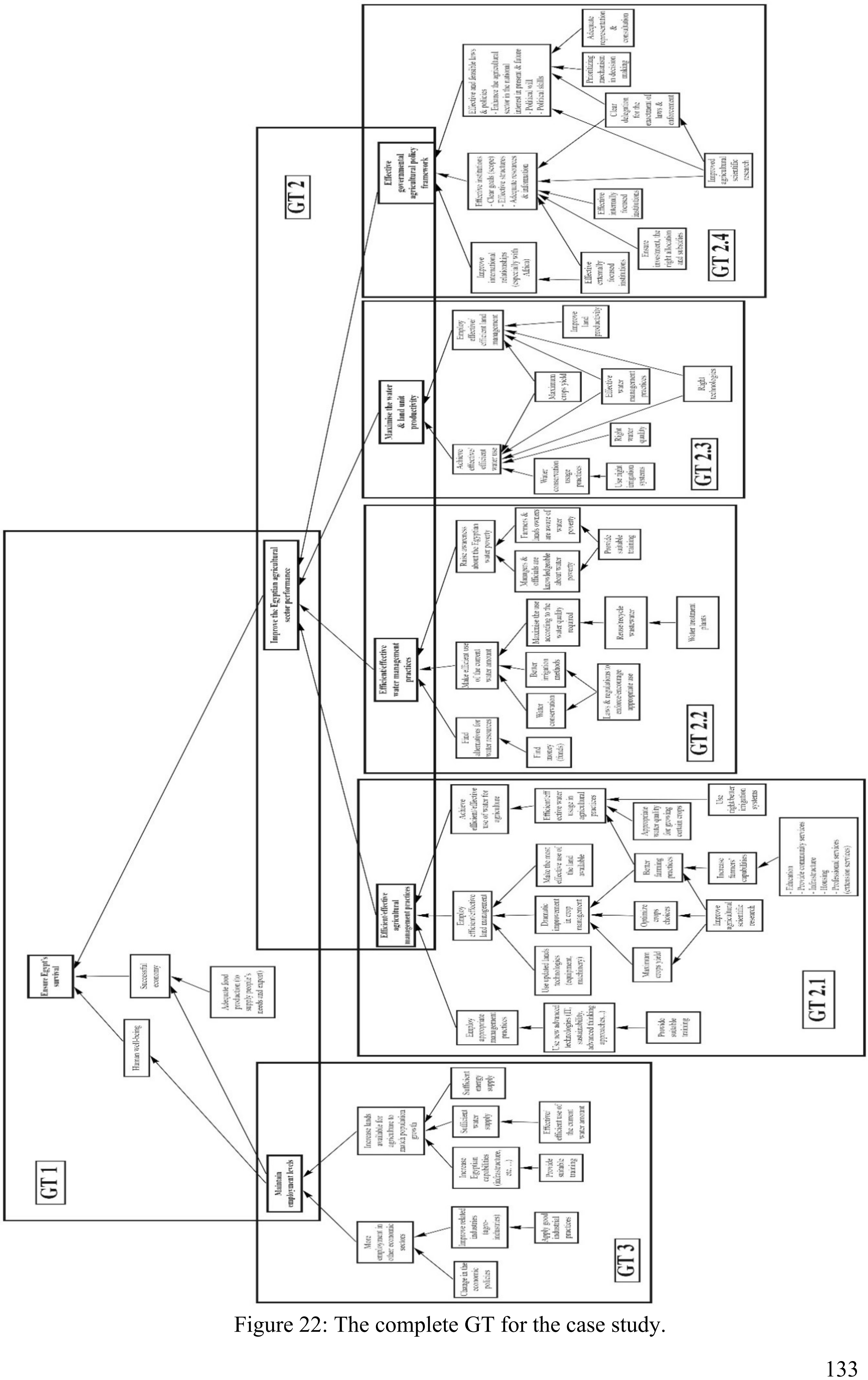

Figure 22: The complete GT for the case study.

As can be seen from Table 26 and Figure 22 above, the results indicate that the main goal, taking into consideration the bigger picture, was to ensure Egypt's survival. In order to maintain this goal, we must have human well-being, a successful economy, and improve Egyptian agricultural performance. It was also required to maintain employment levels, as well as adequate food production (for the population and export) in order to have a successful economy.

The GT analysis has answered the first question "Why change?". In order to improve the Egyptian agricultural sector performance, we must have efficient/effective agricultural and water management practices, maximise the water and land unit productivity, and have an effective agricultural policy framework. The GT analysis also shows that in order to maintain the Egyptian employment levels we must have more employment in other economic sectors and increase lands available for agriculture to match population growth.

What emerges from the GT analysis reported here is that the goals and subordinate goals for our studied case are not being achieved currently because most, if not all, of the CSFs and NCs, are not being met. Additionally, this is expected to be even worse under the GERD. The next tool, therefore, moves on to discuss "What to change?"

7.2.2. Current Reality Tree (CRT) analysis and findings

After answering the first question, CRTs are used to answer the second one "What to change?". CRT analysis starts by listing UDEs and then connects these to their RCs in the form of a tree. The interviews revealed many complaints about the system which were used to compile the list of UDEs.

Data for the CRTs was collected using interview questions 8-11 (Appendix A), which required the participants to identify the UDEs they have experienced within their sector, their root cause, and their effects on the sector and the goals in the current situation (questions 8 and 9) and after the GERD (questions 10 and 11).

These questions were as follows:

8) Are there specific problems (undesirable issues) you have experienced within your sector/work?

9) Why do you identify these problems as being undesirable or bad?

a. What do you feel really causes these problems?

b. How do these problems (undesirable issues) affect the sector's ability to achieve its goals?

c. Does the sector continue to put up with the problem/undesirable issues?

10) In the condition of Egypt's water supply shortage because of the GERD, are you expecting specific problems (undesirable issues) you will encounter within your sector/work?

11) Why do you identify these issue(s) as being undesirable or bad in this certain condition?

a. What do you feel really will cause these problems or undesirable issues?

b. How will the expected problems or undesirable issues affect the sector's ability to achieve its goals?

c. Will the sector continue to put up with the problem/undesirable issues?

Two big CRTs were created to answer the question "What to change?" based on the answers of the participants. The first CRT answers the question regarding the Egyptian agricultural sector in general, while the second one answers the question in light of the expected risks to Egypt's water supply due to the GERD.

The first CRT clarifies the UDEs of this specific current situation by analysing the current state of the Egyptian agricultural sector and exploring the root causes (RCs) of these UDEs, which eventually identifies the core problem.

The CRT is read from bottom to top using sufficient cause thinking, which follows the logic: "If ________, then _________" or "If ________, and if _________, then___________", or "If________, because of_________, then _________." For this study, the first CRT is divided into CRBs that show the RCs and UDEs of the studied system.

7.2.2.1. The first CRT: An analysis of the current agricultural sector

The analysis of the responses to Q8 and Q9 of the interviews identified four main critical RCs that contribute to the agricultural sector UDEs, appearing at the base of the tree. These four main RCs are:

- RC1- Egypt already suffers from water poverty.
- RC2- Climate change and global warming are affecting Egypt. That includes the change in precipitation patterns, the increase in temperatures, and extreme, unpredictable weather events.
- RC4- Population is growing rapidly.
- RC5- Egyptian government displays a lack of political will, support, vision, and cadres (leaders) to support the agricultural sector.

It was clear that most of the participants saw these four factors as the main RCs that led to the UDEs, which the tree should be built around. The first three Current Reality Branches (CRB) show the lateral UDEs of the studied system based on these RCs as represented in CRB 1.1, 1.2, and 1.3. As can be seen, the Egyptian water poverty and rapid population growth give rise to tremendous strains on resources and institutions in the country, which, when accompanied by the effects of climate change, produce a real catastrophe. Off-page connectors are used to indicate arrows between entities that appear on adjacent CRB diagrams, where a number in a circle indicates the entity that appears on another CRB.

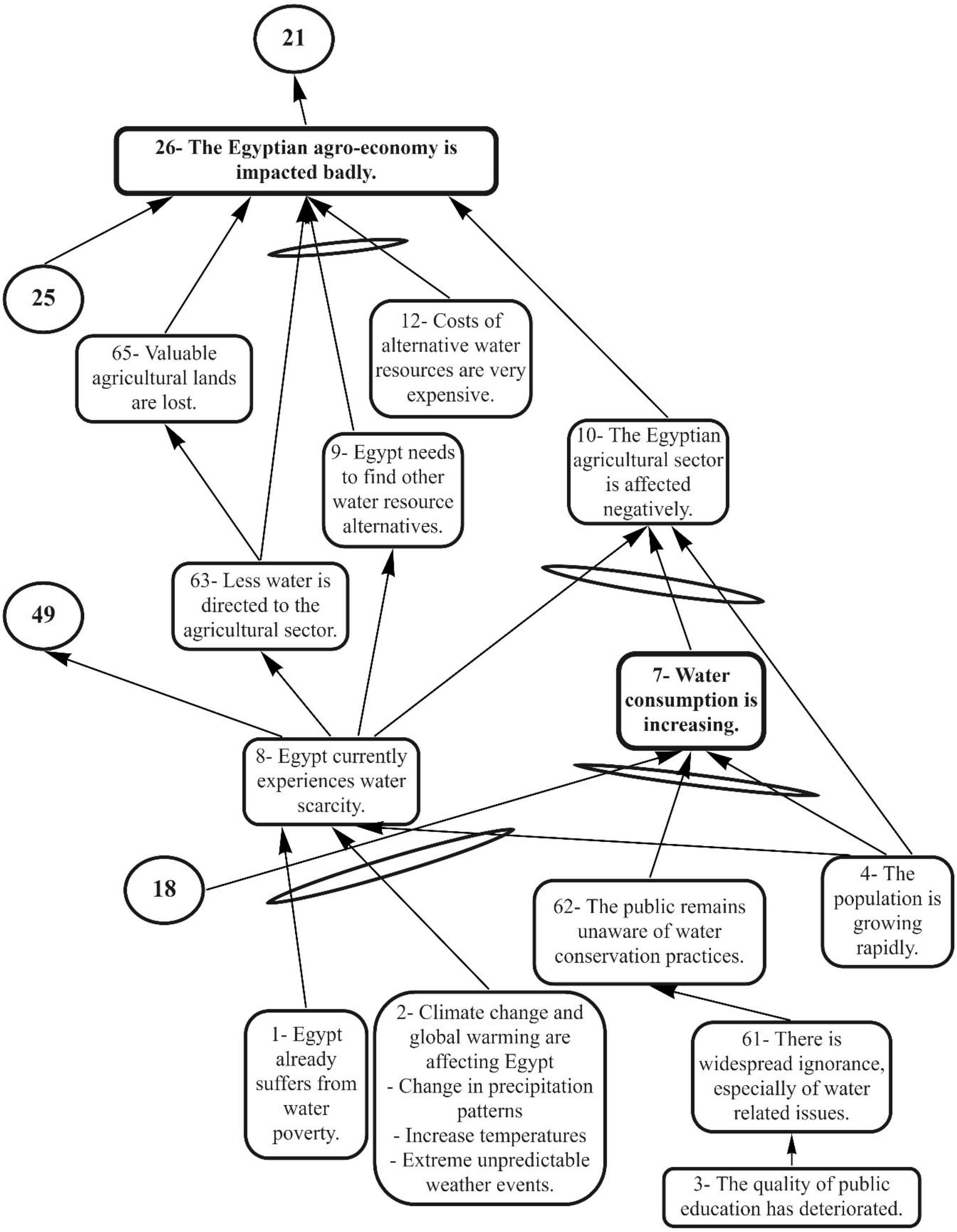

Figure 23: CRB 1.1.[5]

[5] There is a difference between water poverty and water scarcity. The water stress index (Falkenmark indicator) is used to define water scarcity for the population of a region, based on the amount of renewable freshwater that is available for each person each year. If the amount of renewable water in a country is below 1,700 m3/person annually, then this country is experiencing water stress/poverty; below 1,000 m3, it is experiencing water scarcity; and below 500 m3, it is absolute water scarcity (Falkenmark, 1990).

The lack of Egyptian political will, support, vision, and leaders to support the agricultural sector has led to many UDEs. These UDEs are represented in two trees (CRB 1.2 and 1.3). However, the fragmentation of agricultural landholdings joined as one of the RCs for the UDEs at CRB 1.2.

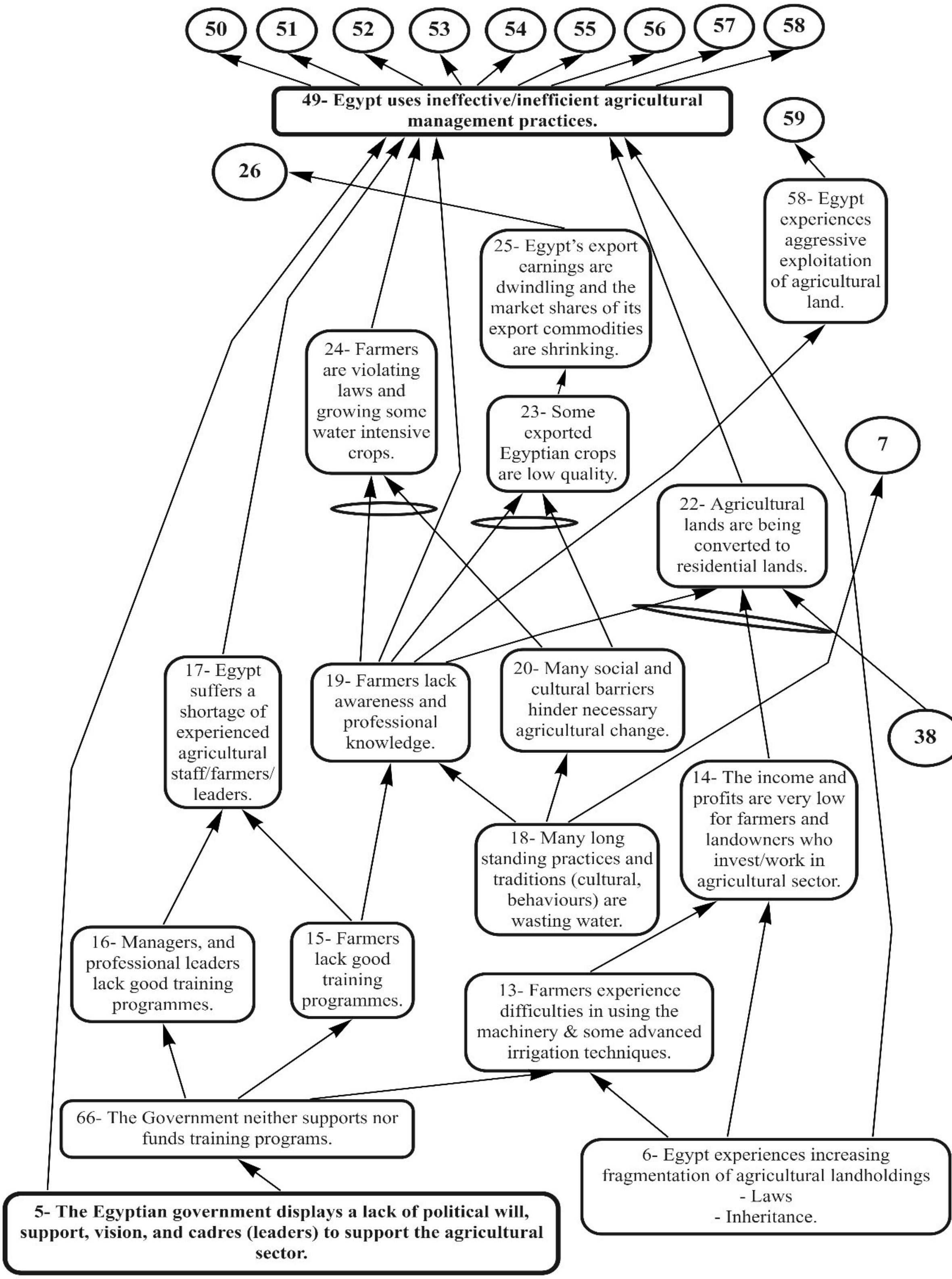

Figure 24: CRB 1.2.

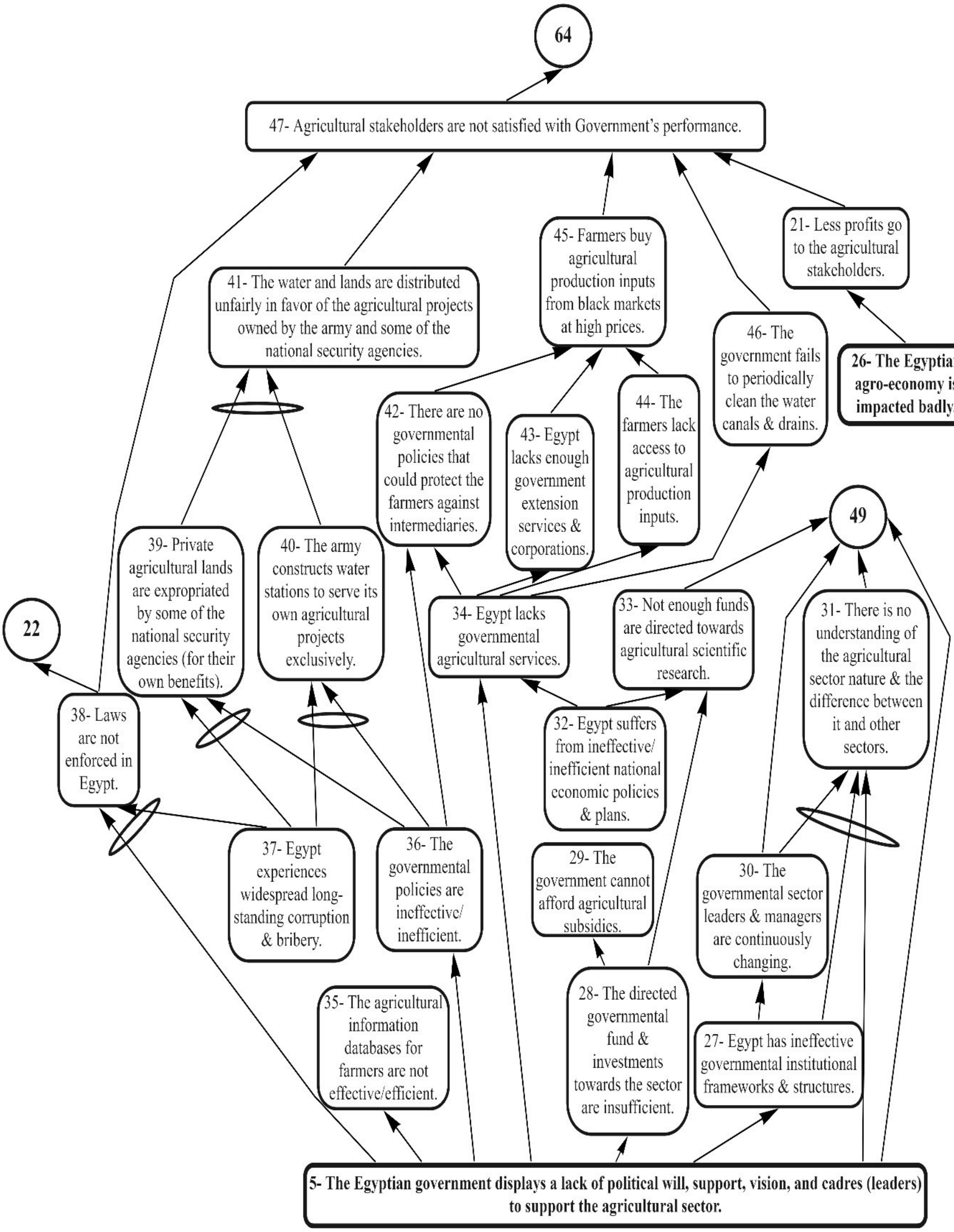

Figure 25: CRB 1.3.

For the fourth and last CRB, one of the UDEs of the other three trees was the base for this tree. This UDE emerged as a root cause for many other UDEs. This UDE is "49- Egypt uses ineffective/inefficient agricultural management practices", as represented in CRB 1.4.

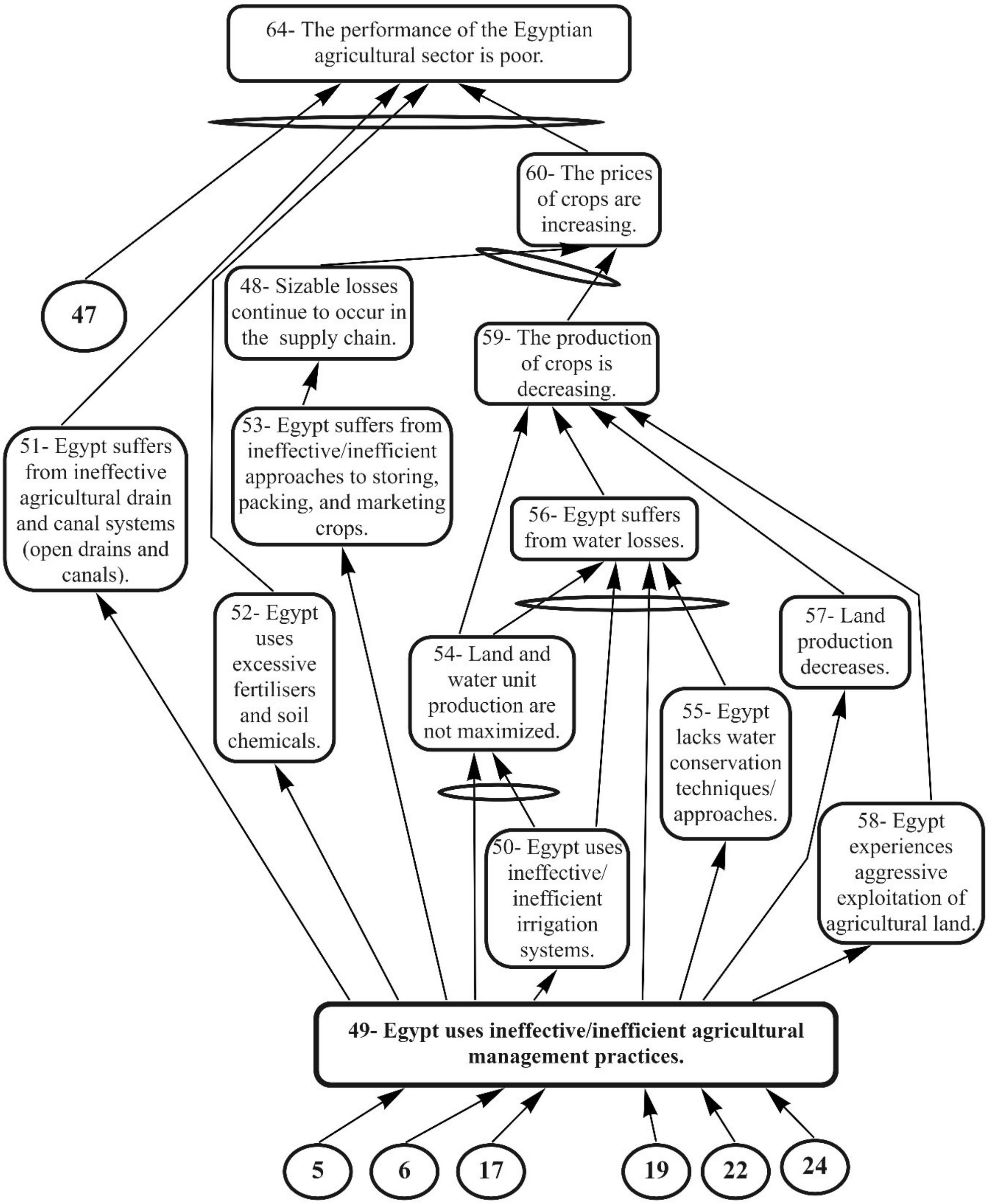

Figure 26: CRB 1.4.

Commentary on participants' remarks

Most of the participants commented that the current UDEs are affecting the sector badly and are expected to get worse. Moreover, they all confirmed that Egypt already suffers from severe water poverty, as all its current available water resources are not enough.

Participant NL1 believed that **resistance to change** is one of the challenges in the agricultural sector. The participant gave an example of farmers who worked in the Delta. They use the same methods of irrigation when they move to other places even removing sprinklers in the new places to operate the irrigation manually as they used to. These comments helped shape UDE 18 “many long-standing practices and traditions (cultural, behaviours) are wasting water”, which in return helped in articulating UDE 20 “many social and cultural barriers hinder necessary agricultural change.”

Participant NL6 explained the challenges the farmers face to market their products. These challenges are represented by the randomness of production; big monopolies that have stifled small farmers; intermediaries (middlemen); and the lack of an organised **marketing system** in the complete absence of any governmental national coordination plans. On the contrary, the government facilitates the imports of the same crops produced by the farmers, which causes considerably more damage due to the farmers’ inability to store these crops. This issue was represented in UDE 53 “Egypt suffers from ineffective/ inefficient approaches to storing, packing, and marketing crops.”

There is a need to first define what corruption is in the agricultural sector, before continuing with the next comments. According to Anik and Bauer (2017), corruption related to the agricultural sector is widespread in some countries. For example, in China, it is classified as the third highest corrupt sector and second when ranked by bribery. There are different forms and types of corruption in the agricultural sector in general. Corruption can take many forms including bribery (unauthorized payment), negligence of duty, embezzlement, nepotism, deception, dealers creating an artificial shortage of agricultural production inputs to push up prices, or adulteration in agricultural production inputs. According to the responses of many participants in this study, all previously mentioned forms of corruption are happening in Egypt, especially the ones relating to the abuse of power by government officials, politicians, the army, or public servants, to serve their interests as will be illustrated in the next comments.

Participant NL6 clarified that there are three types of **intermediaries**: those who market the agricultural production for local consumption, those who export it, and those who sell it to different agro-industry companies. He said, “Those intermediaries are sometimes Mafia ready to control the farmers and buy their crops at the lowest prices. They cruelly exploit the farmers for their own profits”. UDE 42 referred to the intermediaries’ issue; “there are no government policies that protect farmers against intermediaries.”

Participant NL8 claimed that the only way to maintain the agricultural sector is to change the harmful and bad agricultural policies and practices. According to this participant, “The agricultural sector consumes about 85% of Egypt’s water, while it only contributes 11% of Egyptian GDP. In contrast, the industrial sector consumes about 2.5 bcm (about 4.5 % of Egypt’s water), while it contributes 19.9% of Egyptian GDP”. This comment supports UDE 49, “Egypt suffers from ineffective/inefficient agricultural management practices”.

Participant LL5/IL8 agreed with participant NL6 about the Mafia that controls the farmers. He described the “fertiliser dealers” as Mafia as well. He explained that 7 companies in Egypt produce about 22 million tons of nitrogenous fertilisers (two public companies, and five companies belong to the General

Authority for Investment). The local market needs only 9 million tons, and the rest is surplus for export. However, what really happens is that these 9 million tons are not made available for the local market because these companies export more than the surplus to gain more profits. This led to UDE 45; farmers buy agricultural production inputs from **black markets** with high prices.

The participant added that the **efficiency of the Egyptian irrigation and drainage** systems does not exceed 50%. In addition, he commented that many of the agricultural sector's leaders are not specialists and are only working for their personal benefit. He gave an example of the Egyptian Central Agricultural Cooperative Union (CACU). This Union consists of 6304 local agricultural cooperatives in villages, cooperatives in towns and governorates (27 governorates excluding Cairo), and 12 specialised cooperatives. The role of these cooperatives is to help the farmers raise livestock, and get fertilisers, seeds, and pesticides. But most of the people who manage this Union are members of parliament, who do not care about helping the farmers. He added, "Another obvious example is that the president of the Agriculture and Irrigation Committee in parliament is a former police general."

The participant provided another example of the existence of **rampant corruption** in different institutions. He explained that the Agricultural Research Centre used to produce corn-improved seeds, which have very high productivity rates. Meanwhile, a German company working in the same area started working in Egypt. The company started first by conducting workshops and paying huge amounts of money to some of the Centre's managers to help them in promoting their products. Consequently, the centre stopped producing its own improved seeds, while the German company raised the prices of its seeds. This is also included in UDE 37: "Egypt experiences widespread long-standing corruption and bribery".

The participant criticised the performance of the Egyptian government and said, "The government does not care about the miserable lives of farmers. They are not in the same, good position as most farmers around the world". He commented that the government should overcome obstacles that prevent farmers from increasing and improving crop productivity. He also blamed the government for preserving neither the breeds of Egyptian livestock nor the improved Egyptian-produced seeds. The ownership rights over some of these Egyptian seeds have been claimed by other countries because Egypt did not sign or join the International Convention for the Protection of New Varieties of Plants.

Participant LL7 agreed with participant LL5/IL8 regarding **corruption and bribery**. He explained the different forms of bribery politicians sometimes use. They are used with the aim of facilitating illegal services for some farmers to win votes. Examples include giving unequal water rights when assigning water to the farmers, or giving illegal permission to drill wells, or waiving water irrigation fees.

Participant IL2 gave not rotating crops as an example of poor agricultural practice. The participant explained the crop rotation practice as

> "The practice of planting different crops sequentially on a big plot of land. It aims to improve soil health, optimise nutrients in the soil, and combat pest and weed pressure. For example, when the corn harvest is finished, the farmer might plant beans, since corn consumes a lot of nitrogen and beans return nitrogen to the soil."

The participant also clarified that planting the same crop in a huge area helps in reducing water waste and enables the use of agricultural mechanisation. The fact that these practices are often not used is referred to in UDE 49, "Egypt suffers from ineffective/inefficient agricultural management practices."

Participant IL2 also criticised the government's adoption of free market economy policies giving farmers the rights and power to make their own economic choices. The participant said, "Each farmer chooses whatever crops he wants to grow, which may not be serving the country's big economic or agricultural plans." This was included in two UDEs. First, UDE 5 explains that the Egyptian government displays a lack of political will, support, vision, and cadres (leaders) to support the agricultural sector. Second, UDE 32 shows that Egypt suffers from ineffective/ inefficient national economic policies and plans.

The participant explained that the **fragmentation of agricultural landholdings** is a major obstacle in using advanced water and mechanization techniques. He said, "These techniques alone could save more than 15% of water wasted". He also criticised the government's performance by saying, "Government should provide the farmers with high-quality seeds to increase the productivity of crops". The fragmentation was mentioned in UDE number 6, "Egypt suffers from the fragmentation of agricultural landholdings".

Participant IL5 commented that the **excessive use of fertilisers** leads to drainage problems, which consequently would lead to water retention. The participant explained that the increase in nitrate from fertilisers, like any other salt, will increase the osmotic concentration of the soil solution. He said, "The roots of the plant then take up minerals from a more and more concentrated solution. If the solution outside gets too concentrated, there will come a point when the plant is not able to take up any water against the concentration gradient and the plant will start to wilt. Even before this point is reached, the plant will grow more slowly". This comment assisted in the formulation of UDEs 52 and 59, "Egypt is excessively using fertilisers and soil chemicals" and "the production of crops decreases."

As can be noticed, the comments of the participants belonging to the first category - the governmental/national level, which includes politicians and public servants in both agricultural and irrigation sectors, were more concerned with the bigger picture. Participant NL1 talked about the resistance to change, while participant NL6 discussed marketing systems, intermediaries' issues, and the absence of governmental national coordination plans. Moreover, participant NL8 discussed how different sectors contribute differently to the Egyptian GDP and how much water each uses.

The comments of the participants belonging to the second category, the local category which includes local practitioners, such as landowners, farmers, and farmers who own their land, were more realistic and more concerned with details. Participant LL5/IL8 discussed the black market, the efficiency of Egyptian irrigation, and the corruption and bribery problem. Participant LL7 also agreed with the previous participant on how harmful corruption and bribery are to the agricultural sector.

The comments of the participants belonging to the industry category, which includes industry experts in both agricultural and irrigation sectors, were more technical. Participant IL2 talked about the use of the wrong agricultural practices, bad governmental performance, and the fragmentation of agricultural landholdings. Participant IL5 commented on the excessive use of fertilisers.

7.2.2.2. The second CRT: An analysis of the situation due to the GERD

A CRT is generally designed to sum up the issues being faced currently, and to establish their RCs to then ascertain the best ways of addressing them. Having constructed the above CRT for the current situation, the question remained (questions 10 and 11), what would be the situation if/when the GERD becomes operational? The construction of the GERD is almost finished, while Ethiopia already has drawn Nile water three times to test its turbines, as explained in Chapter 2. It is only a matter of time until Ethiopia starts the full filling and operation of the GERD.

To portray this impending reality, it makes sense to extend the first CRT, based on this conditional situation that is almost reality. A second tree has therefore been developed to analyse the expected UDEs of this conditional situation based on the participants' opinions. For presentation purposes, the second CRT is divided into four CRBs that show the lateral UDEs of the studied system. Off-page connectors are used to indicate arrows between entities that appear on adjacent CRB diagrams, where a number in a circle indicates the entity that appears on another CRB.

The analysis of the received answers identified the three new RCs that will contribute significantly to the agricultural sector's UDEs, during the filling and operation time of the GERD, namely:

- RC1: Ethiopia fills the GERD reservoir fast cutting ~30% of the Nile's water annually.
- RC2: Environmental degradation is on the increase (climate change, evaporation rates, global warming).
- RC3: The water volume at the Egyptian border decreases (the amount of the Nile's fresh water decreases).

There was no doubt that all participants saw these three RCs as the base of the most expected UDEs in this case. These three RCs were used to build the second CRT. The first three CRBs of CRT 2 show the lateral UDEs of the studied system based on these effects as represented in CRB 2.1, 2.2, and 2.3.

It can be seen when checking CRB 2.1 that it was more concerned with the UDEs related to the AHD, such as: what would happen to the electricity production and to the species that live in its reservoir.

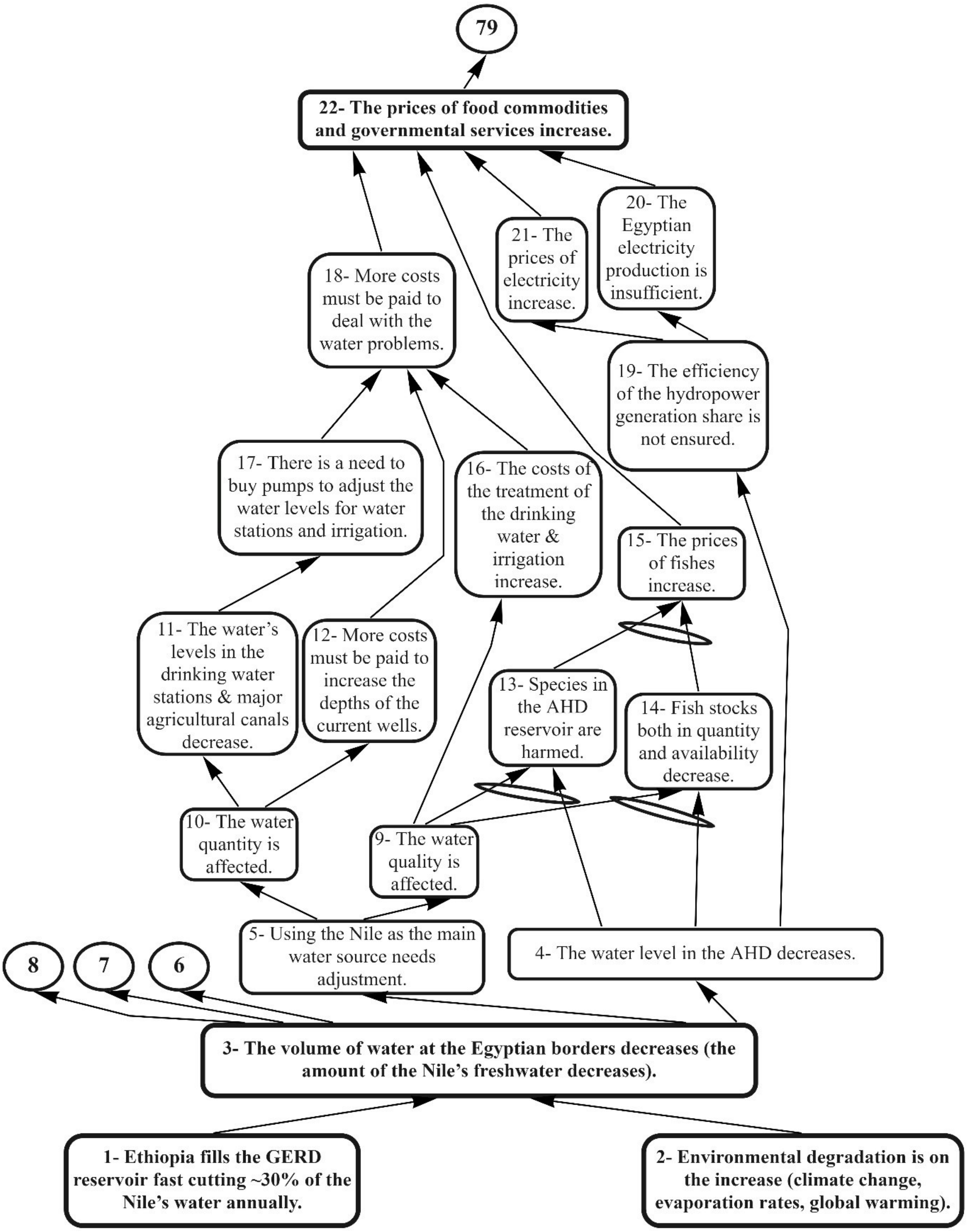

Figure 27: CRB 2.1.

CRB 2.2 was more concerned with the UDEs relating to the severe environmental impacts and the consequences that will happen because of the decrease in the amount of water due to the GERD, such as UDE23: the Mediterranean Sea level rise due to less water flowing from the Nile to the sea, UDE34: the increase of the sedimentation in the Nile's course, and UDE29: the depletion of the fishery resources and crocodiles. The tree explored the insufficient Egyptian water supply that does not meet Egyptian needs.

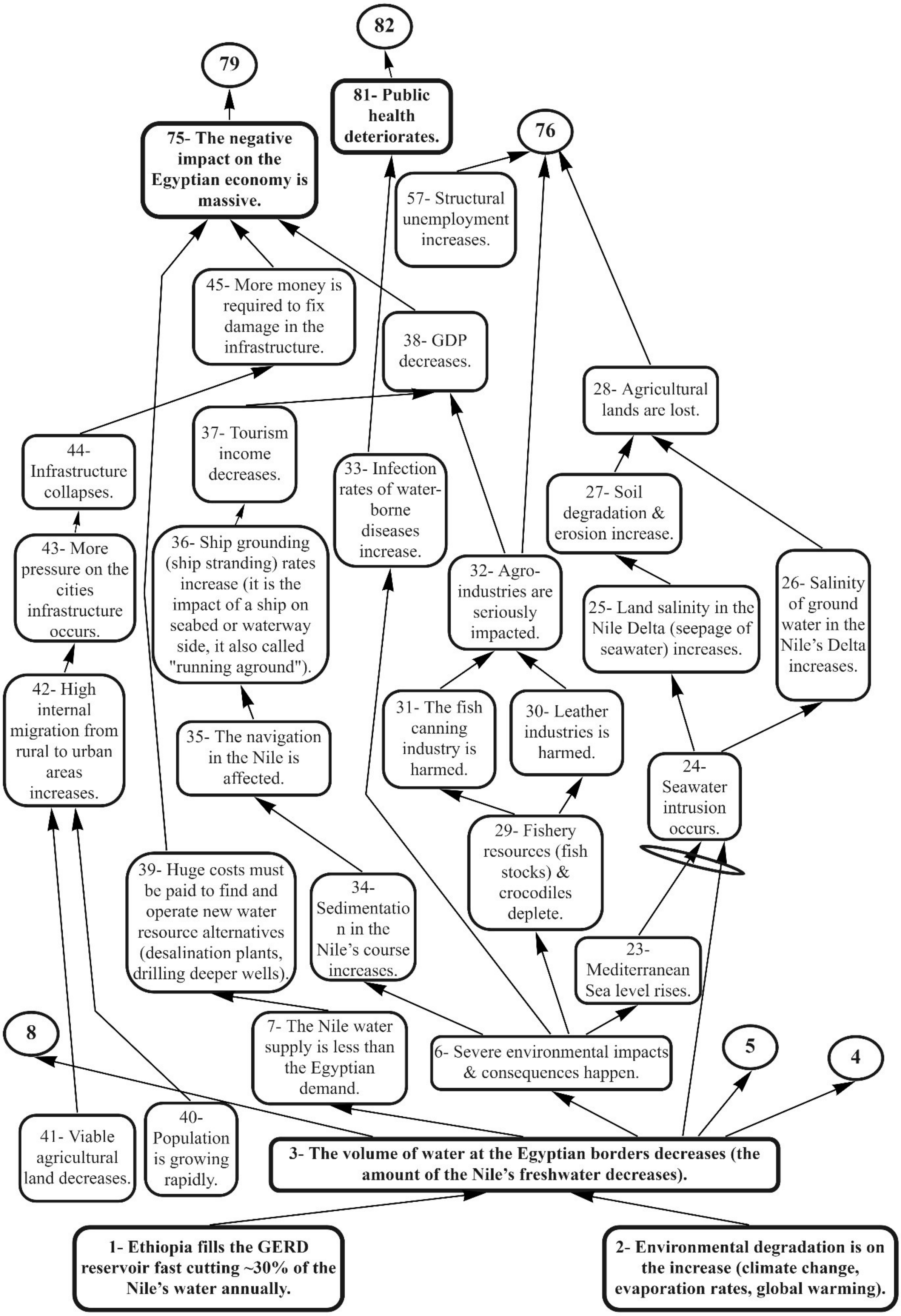

Figure 28: CRB 2.2.

CRB 2.3 was more concerned with the UDEs related to the new issues in the agricultural sector because of the GERD.

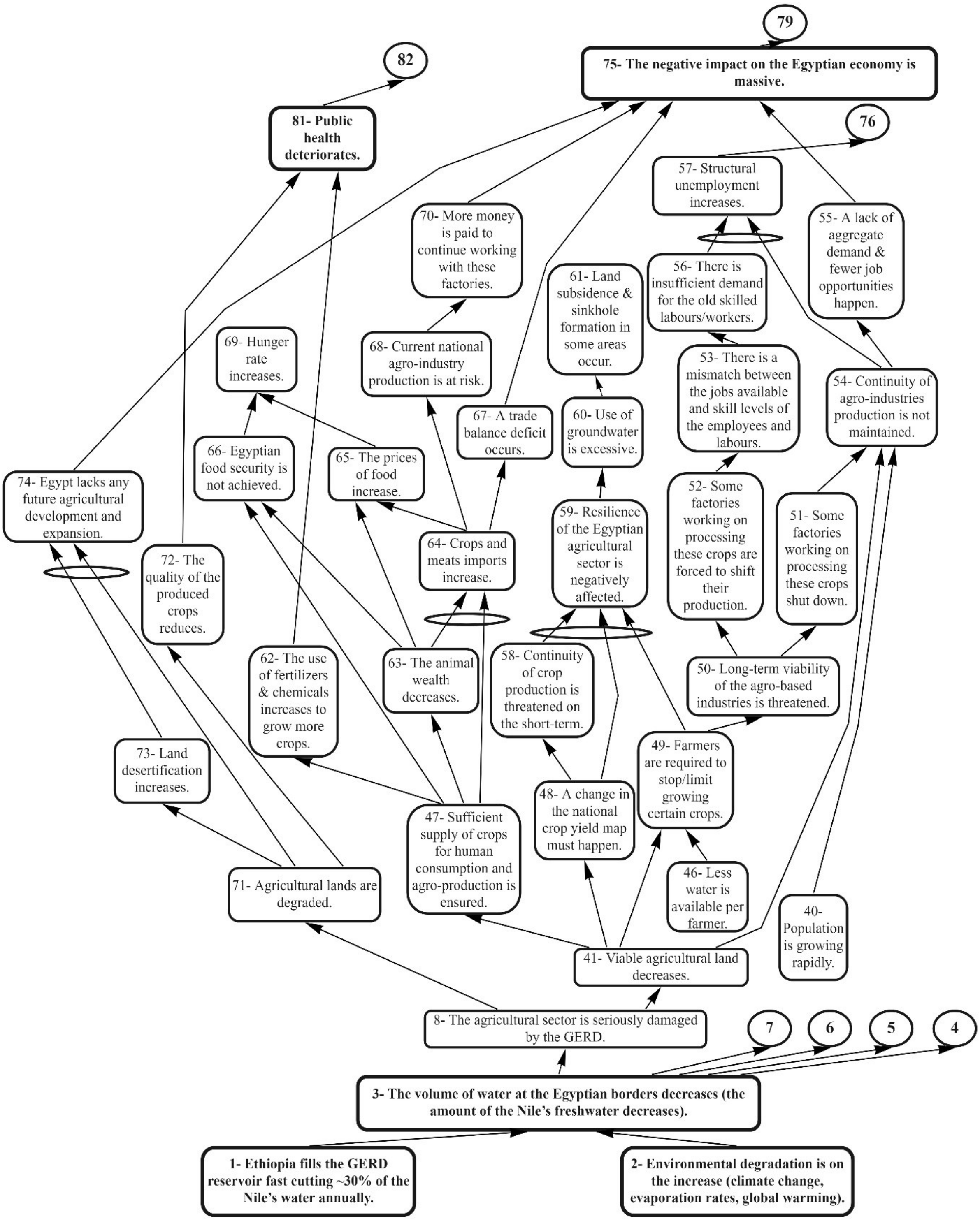

Figure 29: CRB 2.3.

The fourth and final CRB (Figure 30) has, as its main RCs, some of the UDEs from the other three trees, namely:

- UDE75: The negative impact on the Egyptian economy is massive.
- UDE22: The prices of most food commodities and governmental services increase.

- UDE76: Unemployment rate increases.
- UDE81: Public health deteriorates.
- UDE69: Hunger rate increases.

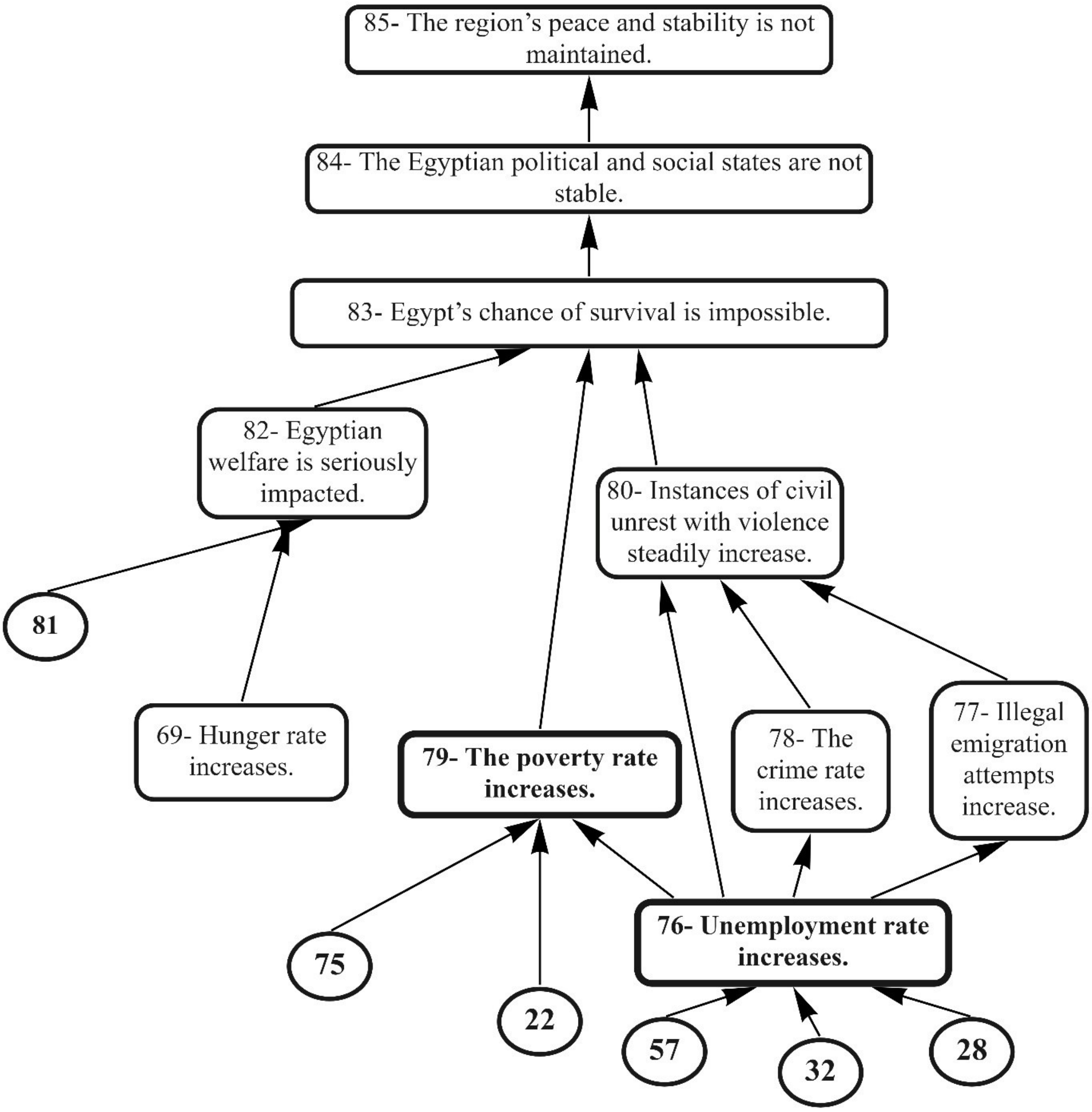

Figure 30: CRB 2.4.

<u>Commentary on participants' remarks</u>

Most of the participants commented that the UDEs would be catastrophic during the filling and operation phases of the GERD, with a full collapse of the agricultural sector predicted because of the water shortage.

Participant NL2 estimated that 2 million acres (20%) of Egyptian agricultural lands are expected to be lost, the participant explained that, for every 5 bcm reduction in water, Egypt will lose a million acres. The total Egyptian agricultural area is estimated to be about 10 million acres, so at least 20% of the Egyptian agricultural lands will be lost. That was represented in UDE 41; "**viable agricultural land decreases**".

Participant NL8 commented that the emigration of workers and labourers will result in the loss of Egyptian skilled workers and professionals. However, those leaving may be ostracised in the other societies to which they migrate, which could create conflict there.

Participant NL5/IL1 predicted that many farmers would abandon their lands. This led them to articulate UDE 8; "the agricultural sector is seriously damaged." The participant also claimed, "**Climate change** will result in losing 15% of Egyptian agricultural production." Climate change was one of the main UDEs for this tree. It was mentioned in UDE 2: "environmental degradation is on the increase (climate change, evaporation rates, global warming)." The participant believed that having a national agricultural plan would be difficult to achieve. The participant clarified that Egypt's annual share of the Nile's water will vary based on the amount of water cut by Ethiopia. He also anticipated the **desertification** of approximately 4 million agricultural acres. It was referred to as land desertification in UDE 73.

Participant LL6 agreed with participant NL5/IL1 on the agricultural lands desertification effect that would occur because of the water shortage. He continued, "These lands cannot be reclaimed later even if the water becomes available (it would require huge efforts, water, and money to re-reclaim lands)".

Participant LL7 claimed that the expected **excessive use of groundwater,** pumping water out of the ground faster than it is replenished over the long term, could result in land subsidence. **Land subsidence** occurs when the soil loses its support below ground; therefore, the soil collapses, compacts, and drops. The participant added, "Consequently, it would cause coastal subsidence in the coastal areas, which may be the main contributor to relative sea-level rise and coastal erosion in coastal environments where subsurface fluids are heavily exploited". These were discussed in two UDEs. Firstly, UDE 60 stated, "the use of groundwater is excessive". Secondly, UDE 61 stated, "land subsidence and sinkhole formation in some areas occur".

Participant LL8/IL11 expected over-cultivation of land by farmers because of the GERD. He defined over-cultivation as "The act or practice of cultivating land to an excessive degree in the growing of crops so that soil quality is **degraded, and productivity is reduced** over this cultivation". He continued, "This is a major cause of soil structure decline, which usually happens due to the loss of organic matter". This was represented through UDE8; "the agricultural sector is seriously damaged", which would lead to UDE71; "the agricultural lands are degraded".

Participant IL2 anticipated the loss of 1 million acres of land for the loss of each 5 bcm of water. Moreover, he estimated the loss of 2 to 3 million jobs per million acres of land lost. These jobs are in both the agricultural and agro-industry sectors. This was mentioned in UDE28; "the agricultural lands are lost", which in return would lead to UDE76; "the unemployment rate increases".

Participant NL2 and participant LL8/IL11 discussed the **risk for Sudan of the GERD's collapse**. However, they admitted that Sudan would have the lion's share of the benefits of the dam. Moreover, Sudan has many other water resources, which means the loss of its share of the Nile water will not have much effect. Participant IL2 discussed Sudan's benefits and said, "Buy cheap electricity from Ethiopia. Sudan is expected to have about 10 to 12 acres suitable for agriculture after the settlement of the Nile after the GERD".

Participant NL1 shared the same concerns about the risk of the GERD's collapse for Sudan, especially in the case of earthquakes with the following points:
- It is a rigid dam constructed using concrete. Whereas the AHD is a non-rigid dam constructed by a rock-fill dam. He explained that the first type does not withstand earthquakes.
- The water weight is another factor that affects collapse in the case of earthquakes.
- Kenya's geological rift splits Africa into two parts. Kenya shares borders with Ethiopia. This is another factor raising concern.
- The GERD's collapse would cause huge damage in Sudan. However, it will not affect Egypt directly, as water could be contained at Toshka Lakes if it arrives in Egypt.

Again, the comments of the participants belonging to the governmental/national level reflected concerns regarding the bigger picture. Participant NL2 discussed the losses of the Egyptian lands. Participant NL5/IL1 talked about climate change and desertification problems, while participant NL8 discussed the emigration of skilled workers.

The comments of the participants belonging to the local practitioners' category were more realistic and more concerned with details. Participant LL6 discussed the desertification problems because of the water shortage. Participant LL7 expressed their worries regarding the excessive use of groundwater that would result in land subsidence. Participant LL8/IL11 argued that soil quality would be degraded, and productivity would be reduced due to the over-cultivation of land.

The comments of the participants belonging to the third category, the industry category, were more concerned with the industries themselves. Participant IL2 mentioned that people would lose their jobs and that unemployment would increase.

<u>The findings of the first CRT</u>

To show the findings of the first CRT, the complete CRT diagram was constituted. The CRT represents the different cause-effect relationships among the various levels of objectives in a nested hierarchy starting from the bottom upwards to answer, "What to change?" in the Egyptian agricultural sector to manage the risks to Egypt's water supply due to the GERD. The CRT diagram has been divided into four CRBs as shown in Figure 31.

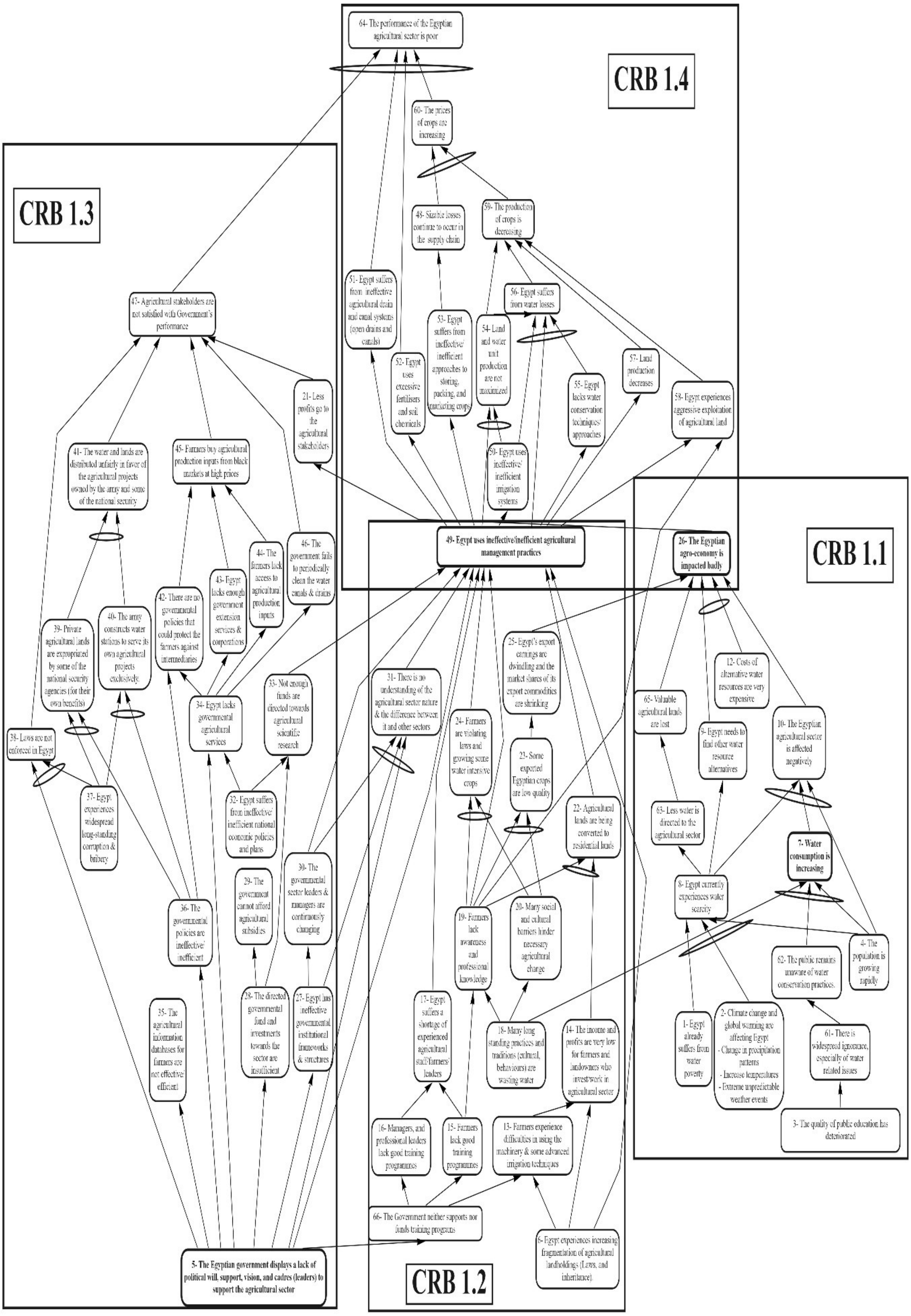

Figure 31: The complete first CRT.

The main and bigger goal of this system was determined after answering the first question by “Ensure Egypt’s survival”. Additionally, the CRT for the Egyptian agricultural sector reveals the current situation and addresses the RCs of problems that tended to have a high negative impact on achieving the system’s goal. The analysis of CRTs identified a long list of issues impacting the achievements of the main goals, which in this case was the subordinate goal “improve the Egyptian agricultural sector performance”, which would consequently affect the main system’s goal “Ensure Egypt’s survival.” The main RCs of the problem are entities numbers:

- 1- Egypt already suffers from water poverty.
- 2- Climate change and global warming are affecting Egypt.
- 4- The population is growing rapidly.
- 5- The Egyptian government displays a lack of political will, support, vision, and cadres (leaders) to support the agricultural sector.
- 6- Egypt suffers from the fragmentation of agricultural landholdings.

The CRT started from the bottom with these main RCs, to end up at the top with the following main UDEs:

- 49- Egypt suffers from ineffective/inefficient agricultural management practices.
- 47- Agricultural stakeholders are not satisfied with Government’s performance.
- 58- Egypt experiences aggressive exploitation of agricultural land.
- 57- Land production decreases.
- 55- Egypt lacks water conservation techniques/approaches.
- 56- Egypt suffers from water losses.
- 54- Land and water units production are not maximised.
- 53- Egypt suffers from ineffective/inefficient approaches to storing, packing, and marketing crops.
- 59- The production of crops is decreasing.
- 60- The prices of crops are increasing.
- The tree ended up with “UDE64: The performance of the Egyptian agricultural sector is poor”.

These RCs and UDEs are needed to be changed to achieve the required goal.

<u>The findings of the second CRT</u>

To show the findings of the second CRT, the complete CRT diagram was created. The CRT represents the different cause-effect relationships among its various levels of objectives in a nested hierarchy starting from the bottom upwards to answer, “What to change?” in the Egyptian agricultural sector to manage the risks to Egypt’s water supply due to the GERD. The complete second CRT diagram is segmented based on the four CRBs as can be seen in Figure 32.

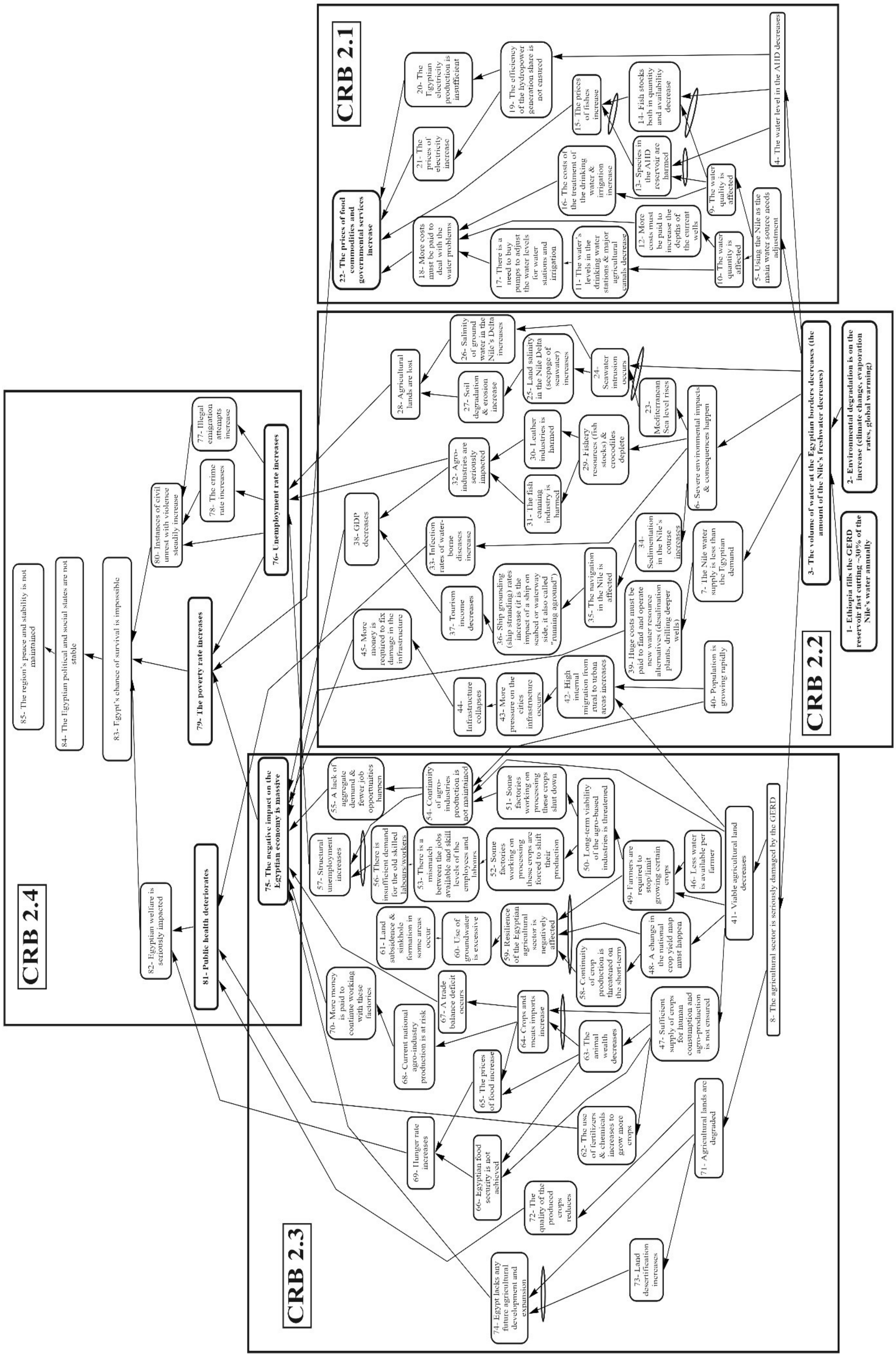

Figure 32: The complete second CRT.

To answer the second question “What to change?” the RCs that would lead to the expected UDEs that impact Egypt’s water supply due to the GERD were determined. The impact on the Egyptian water supply would affect the Egyptian agricultural sector as well. These RCs and UDEs tended to have a high impact on achieving the system’s goal.

The CRT for the Egyptian situation, in this case, reveals and addresses the expected RCs of the problems. The main expected RCs of the problem are (start with entities numbers):

- 1- Ethiopia fills the GERD reservoir by cutting the amount of the Nile’s water annually.
- 2- Environmental degradation is on the increase (climate change, evaporation rates, global warming).
- 3- The water volume at the Egyptian border decreases (the amount of the Nile’s freshwater decreases).
- 4- The level of water in AHD reservoir decreases.
- 5- Using the Nile as a water resource needs adjustment.
- 6- Severe environmental impacts and consequences happen.
- 7- The Nile water supply is less than the Egyptian demand.
- 8- The agricultural sector is seriously damaged.

The CRT started from the bottom with the previous main RCs, to end up at the top with the following UDEs:

- 22- The prices of food commodities and governmental services increase
- 28- Agricultural lands are lost.
- 32-Agro-industries are seriously impacted.
- 37- Tourism income decreases.
- 38- GDP decreases.
- 76- The unemployment rate increases.
- 75- The negative impact on the Egyptian economy is massive.
- 81- Public health deteriorates.
- 78- The crime rate increases.
- 77- Illegal emigration attempts increase.
- 79- The poverty rate increases.
- 80- Instances of civil unrest with violence steadily increase.
- 82- Egyptian welfare is seriously impacted.
- 83- Egypt’s chance of survival is impossible.
- 84- The Egyptian political and social states are not stable.
- 85- The region’s peace and stability are not maintained. This was the highest level of the UDEs.

These RCs and UDEs need to change to achieve the required goal.

It is clear that the two CRTs focused on different aspects. The first CRT was technical and most of the participants’ answers were concerned with the technical causes and UDEs based on the current reality of the Egyptian agricultural sector. However, there is a dramatic difference in the second CRT, the answers were more concerned with the national situation as the GERD is considered a national security matter. The participants viewed the situation as a national crisis, in which Egypt faces intense uncertainty, danger and serious threat regarding its survival.

The causes and UDEs based on the expected reality were extremely frightening, which made most of the participants fear for their lives. This can be seen clearly in the next tool (EC) when the participants were asked to suggest solutions, and few suggested attacking Ethiopia. Some participants claimed that this difficult time needs exceptional rules and procedures accompanied by urgency.

7.2.2.3. The birth of a new tool “Conditional Reality Tree”

The main and bigger goal of this system was defined as “Ensure Egypt’s survival”. I started to work on the CRT to answer the question “What to change”. Two CRTs were formed. The first CRT answers the question regarding the Egyptian agricultural sector in general, while the second answers the question in light of the expected risks to Egypt’s water supply due to the GERD. However, for the second tree, given our new reality, there was a need to make some changes to the CRT tool itself, leading to the development of a new tool.

When I started working on the second tree, I faced a problem that the CRT as a tool works only on a reality that already exists, which in our case is not completely true. Moreover, CRT studies have traditionally employed the bottom-to-top sufficient cause thinking, which follows the logic: “If ________, then _________” or “If ________, and if _________, then___________”, or “If ________, because of _________, then_________.” Moreover, the TP protocol dictates that all entities are worded using the present tense.

However, the second tree is conditional based on a situation that, while imminent, does not exist yet. The construction of the GERD is almost finished, while Ethiopia had previously cut small portions of the Nile’s water three times to test its turbines. It is simply a matter of time before the full filling and operation process of the GERD begins. The second tree analyses the expected RCs of this expected conditional situation based on the participants’ opinions that also determine the expected UDEs in the case of these expected risks.

The TOC TPs tools use two types of logic. Some of them use “necessity logic”, which could be expressed as “In order to achieve A, B must be true.” The other tools use “sufficiency logic,” which is formulated as “If X and Y, then Z.” There was a need to combine these two logics during the development of this new tool. The new tool works based on the two logics together.

First, it applies the “necessity logic” before forming the tree itself. This logic is represented in “In order to form the CRT, the filling and the operation process of the GERD must be true.” One action is necessary before the other can happen. The full-filling process must start before the UDEs formed in this conditional reality tree can happen. However, the condition, in this case, was not related to the logic applied during the creation of the tree; it was the main condition assumed that underpins the shaping of the tree itself. Without assuming this condition, we cannot start forming the tree.

Second, the tree follows the normal “sufficiency logic” as used in the other reality trees, CRT and FRT. It works out all the RCs and UDEs regarding the expected conditional reality due to the GERD by using the logic, "If ________, then _________" or "If ________, and if _________, then___________", or "If ________, because of _________, then_________."

Note that since this tree contains many UDEs—in fact more than the original CRT—it is not appropriate to call it a Future Reality Tree, as this would indicate a desired future reality. The most appropriate name for the new tool would be a Conditional Reality Tree (Cond. RT).

A major advantage of using this new tool is that it combines the TOC's two logics in a way that allows users to gain the benefits of the CRT, portraying a complex situation of concern, even though it does not yet exist. It is ideally suited to situations that represent impending disasters such as climate change/global warming, population growth, or intensification of war/conflict.

In the broad sense "logic" refers to the schematic representation of reasoning procedures. One logic follows the general principle that underpins the articulation of the tree itself, while the other follows the forming principle that establishes the tree. The logic of our new tool is a set of formal, generally applicable rules by which root cause analysis can be utilised even in cases of conditional realities.

7.2.3. Evaporating Cloud (EC) analysis and findings

ECs are used to generate novel ideas to break an impasse and to help answer the third question "What to change to?". The EC is used to depict the conflict of opposing ideas (see schematic in Figure 33). The top half of the Cloud represents one view (ABD), and the lower half represents the opposite view (ACD '), while D and D' cannot be done together, represented by the jagged arrow. Assumptions underlying the necessity links, represented by straight arrows, in the EC are then surfaced and broken to provide solutions to the conflict. Both requirements, B and C, must be achieved to attain the objective.

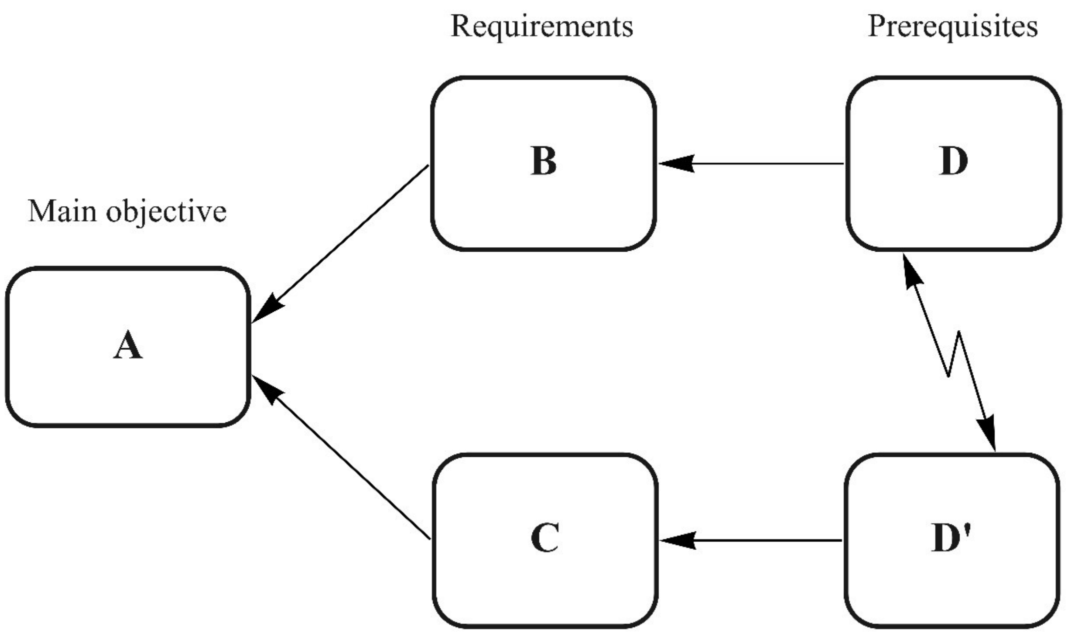

Figure 33: The EC.

Data for the ECs was collected using interview question 12 with its 2 parts: a and b (Appendix A), which asked the participants about their expectations of experiencing any conflicts or dilemmas because of the UDEs now, and in the future once the GERD starts operating, as well as their suggested solutions. These questions were as follows:

> 12) Do you expect to experience any conflicts or dilemmas because of these problems or undesirable issues? (Now, and in the future, once GERD starts operating)
> a. Please describe the conflict or the dilemma.
> b. What suggestions would you recommend to help alleviate this future problem or eliminate the conflict?

Before embarking on the EC analyses, the researcher re-read the answers of the participants. Many answers discussed different problems such as: the production of crops, the loss of agricultural lands, the amount of water available to Egypt, and the lack of governmental support, will, or vision regarding the agricultural sector. Other answers discussed problems related to what would happen when the GERD started filling and operation, such as: the decrease in electricity generated by the AHD, the increase in the unemployment rate, or issues related to agro-industry. Other participants had concerns regarding the national status.

It took me a while to connect the ideas and now I can see the missing piece. After some time of reading the answers, it became clear that the answers could be grouped under three main themes. These three themes are: problems/conflicts related to the agricultural sector, problems/conflicts related to the expected risks to Egypt due to the GERD, and problems/conflicts at the national level.

I started to assign the answers of the participants under each theme, first with the problems related to the agricultural sector. Participant NL1 talked about the loss in agricultural production, participant NL2 talked about land losses, participant LL3 discussed the wrong agricultural plans, while participants LL4 and LL5 complained about wrong agricultural practices.

All the participants' views regarding the agricultural sector were classified through three main problems, which led to three different individual clouds (EC1, EC2, EC3). These three individual ECs were later combined using a consolidated cloud diagram. The consolidated cloud diagram comprises three individual ECs combined into one higher level EC (Cox et al., 2003), in this case, a cloud for the agricultural sector EC4 that summarises and gathers these 3 individual ECs (EC1, EC2, EC3) under the main theme of the improvement of the Egyptian agricultural sector. This set of 4 ECs will be referred to as the first consolidated cloud diagram for Theme I: Agricultural sector.

The same process was adopted for the second and third themes, to form two more consolidated cloud diagrams. Having thus analysed the three themes separately, they were then combined in a hierarchy of relationships, portrayed in schematic form in Figure 34.

It is important to confirm that all 13 clouds were constructed to present only the Egyptian side. The stakeholders in all clouds represent Egypt's government and the Egyptian decision makers. The 13 clouds are all investigating dilemmas (between two different decision alternatives for the same decision maker), not conflicts between different stakeholders. This research is more concerned with the Egyptian situation and studies the risks to Egypt's water supply.

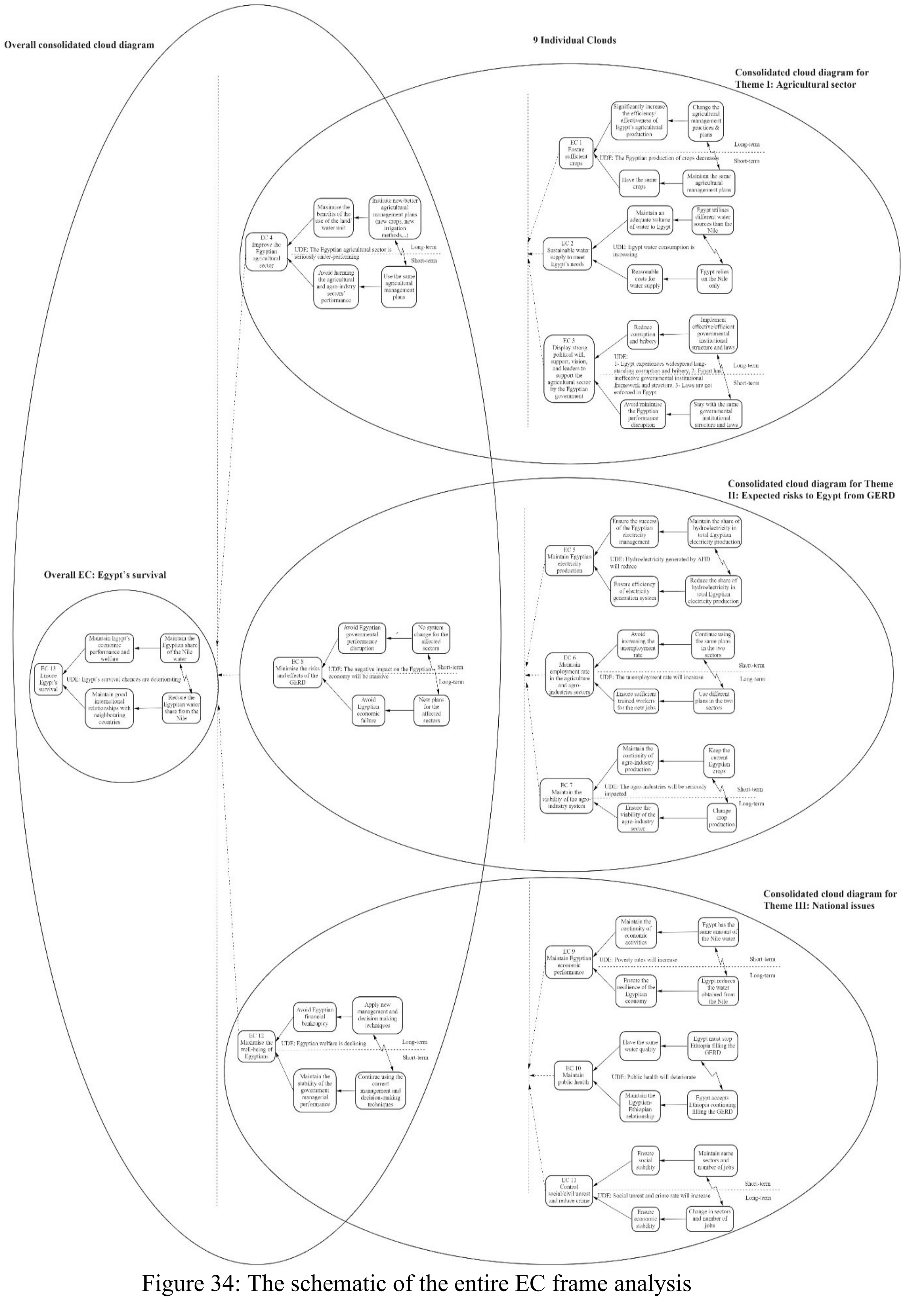

Figure 34: The schematic of the entire EC frame analysis

Theme I: Egyptian agricultural sector

The first consolidated cloud diagram discusses three main problems affecting the improvement of the Egyptian agricultural sector. First is the efficiency and effectiveness of agricultural management. This problem was identified by gathering many answers related to crop production, irrigation methods, the quantities produced per unit of land and water, ineffective agricultural drains and canal systems, and the excessive use of fertilisers and soil chemicals.

The water supply required to meet Egyptian needs was the second conflict, in which participants were concerned about the lack of water (Egypt already suffers from water poverty). The third main conflict surrounds the lack of Egyptian political will, support, vision, and leaders to support the agricultural sector. This includes the ineffective governmental institutional framework and structures, ineffective governmental policies, the lack of enough government extension services, laws (whether they were inadequate laws or ineffective or unenforced laws), and finally, widespread and long-standing corruption and bribery.

Solutions to an EC are usually found using a methodical listing of assumptions and injections to break those assumptions. However, Mabin et al. (2009) also recommend a "quick way" for generating breakthrough solutions. Both methods are illustrated for the first EC.

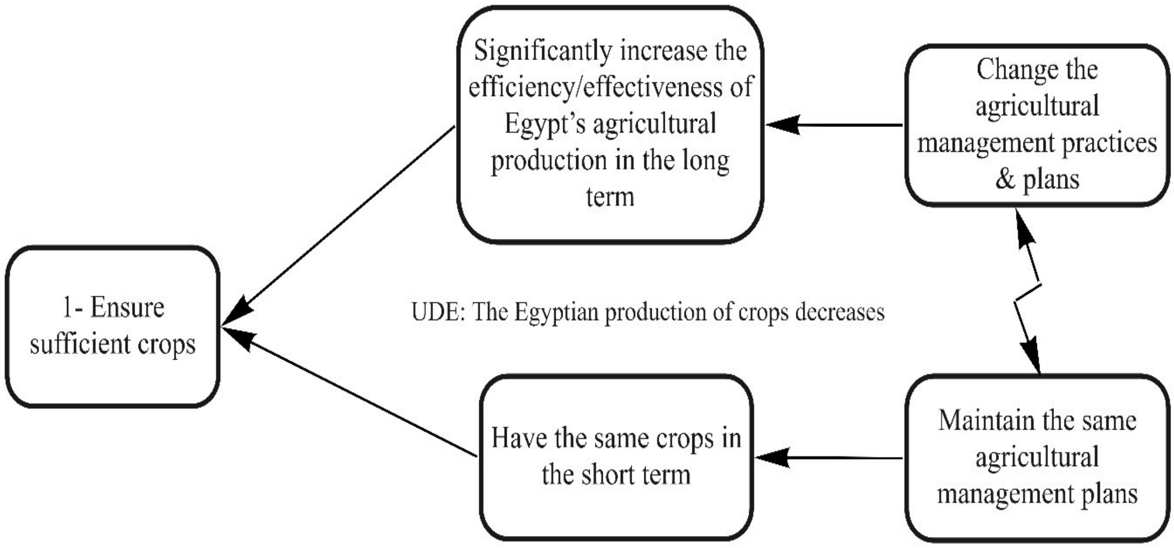

Figure 35: EC1.

An EC is read from left to right and has an imaginary line to depict two different views. As explained in Chapter 3, the opposing views that represent the conflict must be determined first (D, D'). Then the needs should be established (B, C). The logic must be checked by reading the EC from left to right by using "In order to ... we must ...". Finally, the shared objective must be established, and the full cloud checked. The assumptions of each side should then be surfaced so that we can evaporate the cloud and end the dilemma/conflict by breaking these assumptions. Injections represent the ideas that serve as a starting point to solve the conflict and lead to a win-win solution (Cox et al., 2005).

The methodical way to solve EC1:

EC1			
	State the arrow	Add the missing assumptions	Devise injections (to break each assumption)
A	A is desirable because	- Egypt needs to feed its people. - Egypt needs to produce enough crops for current Egyptian agro-industries.	Feed people and supply agro-industries in some other way.
AB	In order to A, Egypt must B because	1- Once the GERD comes into operation, there will be significant losses in land and water; 2- The population is increasing; 3- The Egyptian agricultural sector is the main provider of crops to feed the people and supply agro-industries.	- Import crops from international markets. - Grow crops elsewhere outside of Egypt by renting lands. - Get water some other way. - Cut back on the consumption of crops. - Control population growth.
BD	In order to B, Egypt must D because	- The current Egyptian agricultural management practices and plans are neither efficient nor effective enough and certainly will not provide what is needed in the future. - The water and land units are not efficiently used. - Most of the Egyptian crops grown currently are water-intensive crops. - The irrigation methods promoted by current plans used are wasting a lot of water. - Huge losses in crops during storing, harvesting, or during loading the trucks.	- Use advanced water technologies and techniques to conserve water and reduce waste due to domestic and industrial activities, without changing agricultural practices. - Maintain the agricultural management efficiency/ effectiveness by focusing on the optimum use of other resources than water and land.
AC	In order to A, Egypt must C because	-The production of Egyptian crops is sufficient in the short term. -These kinds of crops are needed for the Egyptian agro-industries and to feed the people.	- Import crops from international markets. - Grow crops elsewhere outside of Egypt by renting lands.
CD'	In order to C, Egypt must D' because	- Changing the agricultural management practices and plans to save more water would mean a change in the crops grown due to the need to grow less water-intensive crops and such	- Change the plans for specific lands and areas that already grow crops for export where the disruption will not adversely impact the local population directly.

EC1			
	State the arrow	Add the missing assumptions	Devise injections (to break each assumption)
		disruption will cause production to drop in the short term.	- Limit adverse impacts from a drop in export earnings by reducing corruption.
DD'	D and D' are in conflict because	- Cannot preserve the same agricultural management plans and change them at the same time.	Apply the new plans gradually or for specific agricultural lands.

Table 27: Injections and assumptions for EC1 using the methodical way.

The quick way to solve EC1:

EC1	
In order to have “A”, Egypt must do/have “B” & “C”	In order to ensure sufficient crops (A), Egypt must ensure the efficiency/effectiveness of Egypt’s agricultural management in the long term (B) and have the same crops in the short term (C).
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt can ensure the efficiency/effectiveness of Egypt’s agricultural management in the long term (B) AND maintain the same agricultural management plans (D') if Egypt: Inj BD1- Use advanced water technologies and techniques to conserve water and reduce waste without changing the agricultural practices; Inj BD2- Apply the new plans gradually or for specific agricultural lands; Inj BD3- Change the plans for specific lands and areas that already grow crops for export where the disruption will not adversely impact on the local population; Inj BD4- Maintain the agricultural management efficiency/effectiveness by focusing on the optimum use of other resources than water and land.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt can have the same crops in the short term (C) AND change the agricultural management practices and plans (D) if Egypt: Inj. CD'1- Import crops from international markets; Inj. CD'2- Grow crops elsewhere out of Egypt by renting lands in other countries; Inj. CD'3- Use different methods that use water and land more efficiently to produce the same crops.
The UDE that needed to be avoided	UDE59: The Egyptian production of crops is decreasing.

Table 28: Injections and assumptions for EC1 using the quick way.

Commentary on participants' remarks
Some insightful viewpoints from participants that have been captured in these EC diagrams are worth noting here. Participant NL2 explained that Upper Egypt consumes electricity generated from the AHD, especially for the aluminium industries there. The decrease in the water level will reduce the generation of this electricity. There was mention of 2 new power stations being built in secret, but the status is not known.

Participant NL5/IL1 expected bloody fights to break out between farmers over water to irrigate their lands because of water shortages. He said, "It could turn into **terrible massacres**".

Participant NL4 expressed concerns regarding the **Egyptian-Sudanese relationship**. He claimed that "Sudan could choose to side with Ethiopia because of the benefits they would gain, such as cheap electricity, which could damage the Egyptian-Sudanese relationship." He suggested that Egypt should support Sudan financially and sell them cheap electricity as well.

Participant NL4 also explained that cooperation between the three countries is the only way to end this dispute. **New agreements** should take place. He continued,

> "Construct new road networks across the boundaries, develop a trilateral agreement on agriculture, and establish new plans to maintain food security that would be enough to solve most of the problems these three countries are suffering from. It also utilises the three countries' strengths. Sudan is considered one of the most fertile lands in Africa; Egypt has great cadres, professionals, and agricultural experience that can benefit the other two countries; and Ethiopia could help with the cheap electricity generated by this dam".

Participant IL2 suggested creating a **joint agricultural integration area** in agreement with Sudan and located in eastern Sudan. He claimed,

> "This area has always been extremely fertile, and it is estimated at 8 to 12 feddans (bigger than the cultivated area in Egypt), Ethiopia provides water, and Egypt provides expertise, labourers, and money to fund the project (international entities like the WB or other institutions could help with funding). The establishment of regional integration through common economic interests between the three countries will defuse the crisis".

He gave Germany and France after the end of World War II as an example of such integration. He suggested creating a free trade area as an integration zone in Ethiopia next to the lake, in Sudan, or in the Halaib Triangle in Egypt (Halaib Triangle is a disputed area of land located at the Egyptian-Sudanese border, over which both Egypt and Sudan have claimed their sovereignty). He said, "This idea might kill two birds with one stone, ending the dispute between the three countries over the GERD, as well as the Egyptian-Sudanese dispute over Halaib". This free trade area will allow the citizens of the three countries to move and enter freely without passports.

Participant IL2 also advised that Egypt should **reclaim its role as one of the most influential countries in Africa** by maintaining its historical and cultural ties dating back thousands of years with its African neighbours. Egypt used to look to the south. However, since the assassination attempt of Egypt's then-President Hosni Mubarak in Ethiopia's capital, Addis Ababa, in 1995, Egyptian-African relations have been in decline. He continued, "The Egyptian foreign policy faces many challenges, which cast a shadow over the ties that link Egypt with the African continent". This thought was also shared by participant LL8/IL11, who said, "Since the assassination attempt of Hosni Mubarak, relations between the two countries did not get back to normal." He continued that Egypt used to send aid to Ethiopia and offer scholarships to Ethiopians to study in Egypt. He also argued that the unstable Ethiopian current political situation is a factor that increases tension and inflames the conflict between the two countries.

Participant IL2 also explained that before constructing the dam, Egypt could take different steps that would protect its rights to the Nile's water, before the situation got that complicated. He said that Egypt should have supplied Ethiopia with electricity back then or helped them construct power stations. He added that Ethiopia asked Egypt for help to plant 100 million trees in Ethiopia before the construction of the dam. It was for environmental purposes and to increase the rainfall upstream, which eventually would increase the amount of Nile water. If this was done, Ethiopia would be able to fill the dam's reservoir and Egypt would be able to get the same share of the Nile's water. He said, "To increase the shared resources instead of fighting for the current limited ones".

Some participants saw that going to war with Ethiopia could be our last option if Egypt wants to "turn the table upside down".

Surprisingly, none of the participants discussed the GERD's environmental impacts as conflicts or problems when talking about the expected risks to Egypt because of the GERD, although they had listed them as UDEs. The explanation from my view is that the current short-term threats, which they already suffer, are urgent and catastrophic, in comparison with the long-term environmental impacts. The long-term impacts thus seem less important to participants. Despite this oversight, their answers clearly showed consistency throughout each interview.

The findings of the ECs

In the EC frame analysis, ECs were created to answer the question "What to change to?" regarding the risks to Egypt's water supply due to the GERD. A total of 13 ECs were constructed, comprising three consolidated cloud diagrams that address the three main aspects of the risks to Egypt's water supply due to the GERD on the Egyptian agricultural sector based solely on the participants' views.

Theme I: Egyptian agricultural sector

The first consolidated cloud diagram is concerned with problems related to the agricultural sector itself, represented through individual clouds EC1, EC2, EC3, and EC4. The parent cloud of these three separate consolidated cloud diagrams, EC4, can be seen as a short-term pain versus long-term gain conflict. The researcher found that short-term harm may be inevitable in order to achieve long-term improvements. Some of the proposed injections for this cloud came up with ways that this harm could be mitigated or prevented as the industry goes through the required changes.

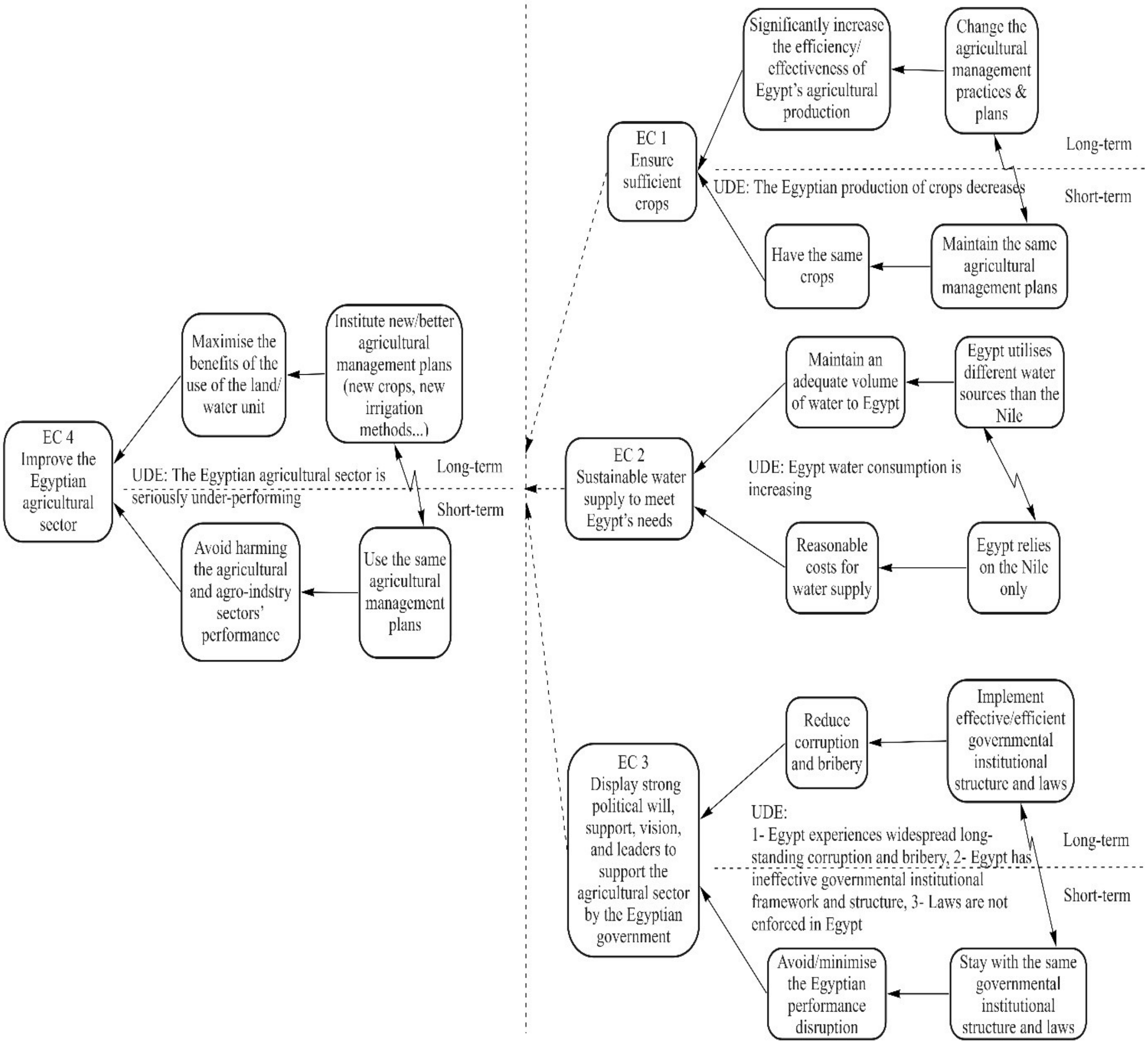

Figure 36: Consolidated cloud diagram for Theme I - Agricultural sector.

Theme II: Expected risks to Egypt due to the GERD

The second consolidated cloud diagram is concerned with problems related to the expected risks to Egypt in general and to Egypt's water supply in particular, due to the GERD, represented in clouds EC5, EC6, and EC7, and the combined cloud, EC8. Again EC8, the parent cloud of these three clouds, can be seen as the pain that Egypt would suffer in the short-term for the long-term good. The researcher found that most proposed strategies tend to be about making changes in such a way that stability is maintained as much as possible, while changes for the better are progressively undertaken. Meanwhile, any shortfalls or issues will be dealt with. This must be planned and led by a strong government that should have a strong political will, support, vision, and good plans to support the agricultural sector. Additionally, this should be supported with training, good education, anti-corruption measures, and law enforcement.

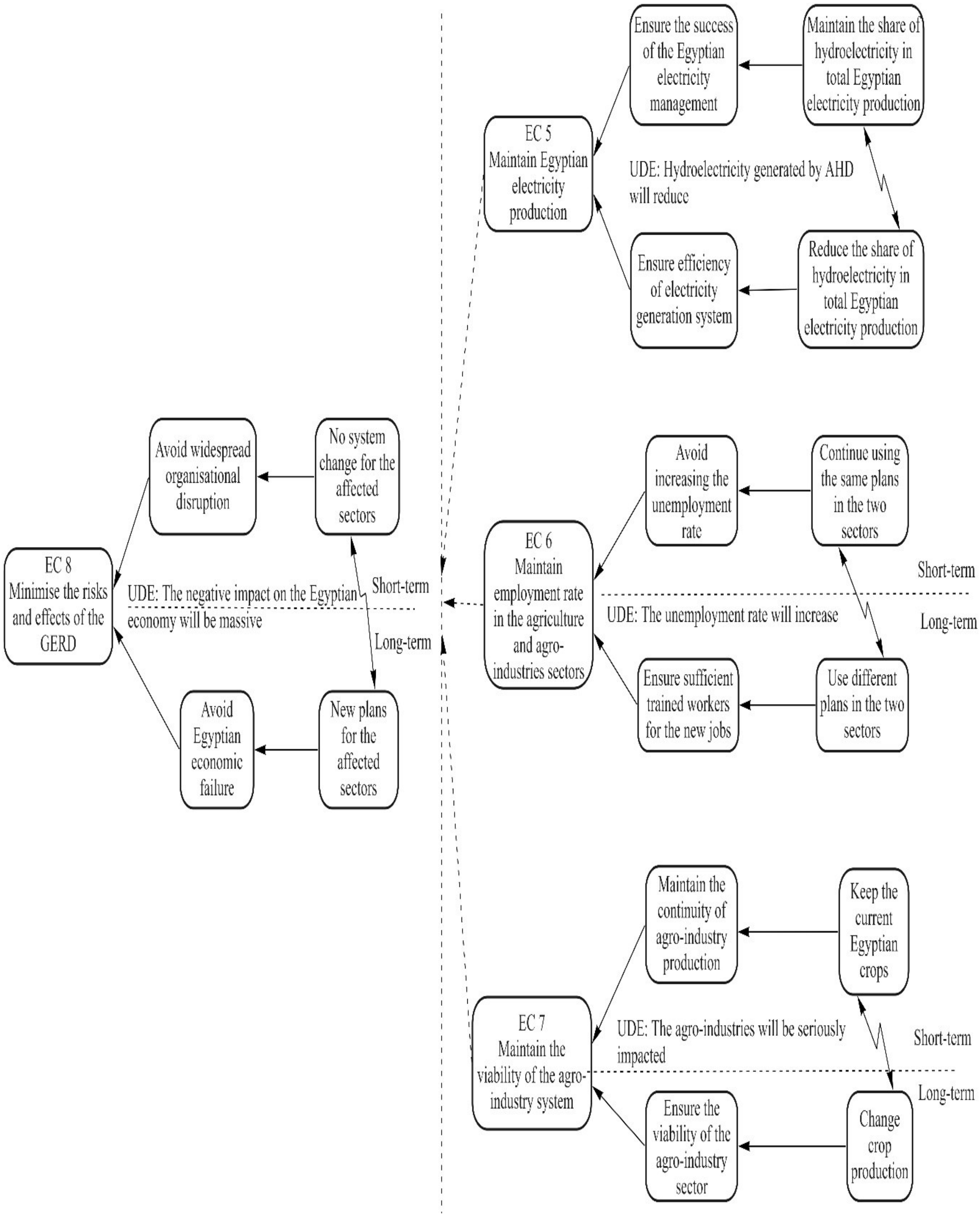

Figure 37: Consolidated cloud diagram for Theme II – Expected risks to Egypt from GERD.

Theme III: National issues

The third consolidated cloud is concerned with problems at the national level, represented by individual clouds EC9, EC10, and EC11, and the combined EC12.

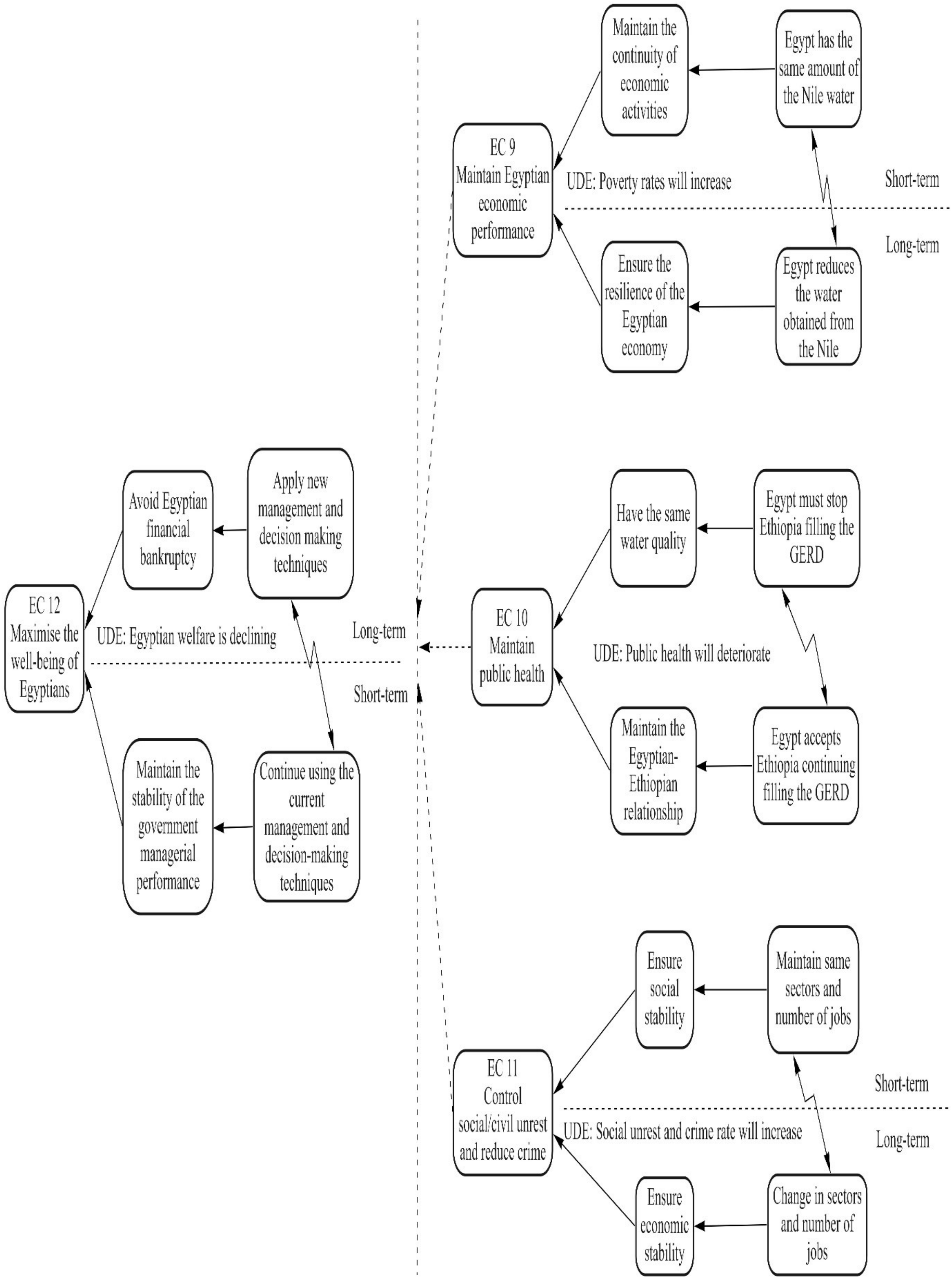

Figure 38: Consolidated cloud diagram for Theme III - National issues.

Overall consolidated cloud diagram

Lastly, the three parent clouds of the three different consolidated cloud diagrams, EC4, EC8, and EC12 were combined to generate the overall consolidated cloud diagram (core conflict cloud). This consolidated cloud diagram EC13 focuses on ensuring Egypt's survival.

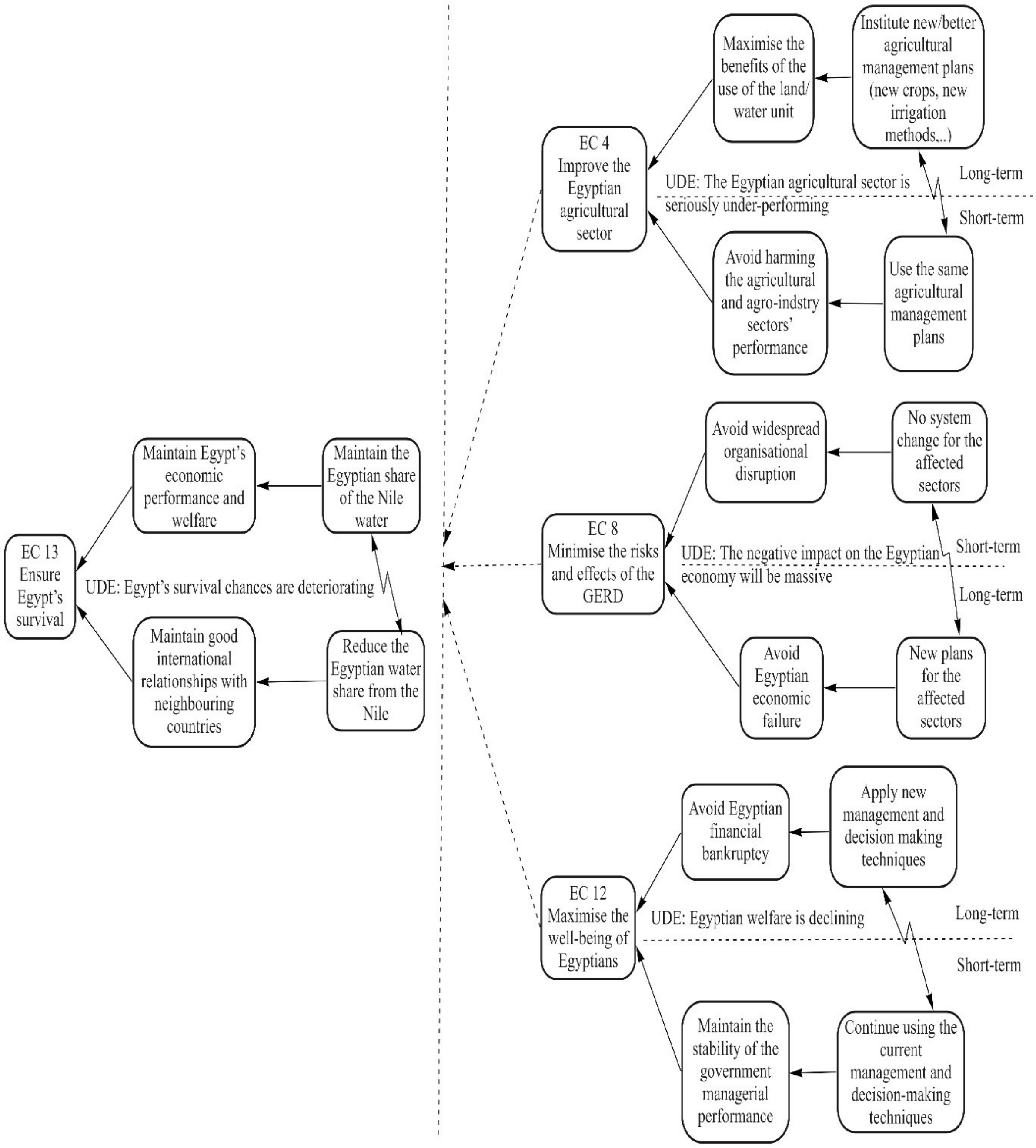

Figure 39: Overall consolidated cloud diagram.

To summarise, the three main themes contributed to constructing the overall EC. In order to ensure Egypt's survival, Egypt must improve the Egyptian agricultural sector, minimise the risks of the GERD construction on Egypt, and maximise the wellbeing of Egyptians.

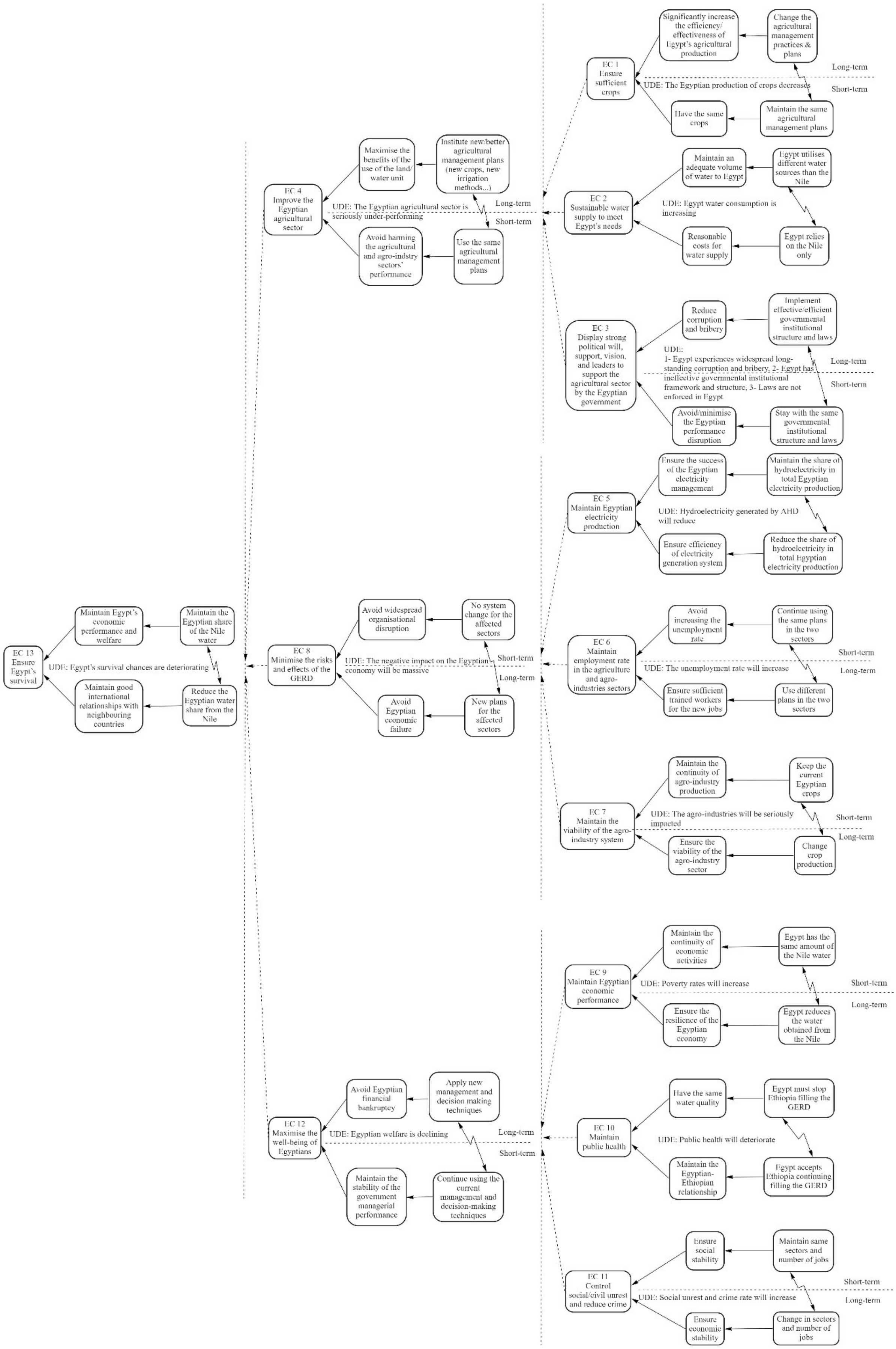

Figure 40: The complete ECs.

The main goals of the GTs appeared as the main objectives for some of the ECs, while the UDEs of the CRT and Cond. RT appeared as the conflicts and problems that each EC tried to solve. The main goal in this study was defined as "ensure Egypt's survival", while some other sub-goals were found to be: "improve the Egyptian agricultural sector", "successful economy", "human well-being", and "maintain employment levels". The main goal of the GTs, "ensure Egypt's survival", was found to be the main objective of the last generic EC in this study as well, while the other sub-goals were represented in the individual ECs in some other parts of the EC map. An example of how these goals were represented in ECs can be found in EC4, whose main objective was to "improve the Egyptian agricultural sector". Some other goals, like "successful economy" and "human well-being", were represented in the consolidated cloud diagrams, whose main objective was to "maximise the well-being of Egyptians". "Maintain employment rate" was represented as a goal in the individual cloud EC6.

The UDEs of the CRT and Cond. RT provided the basis for the conflicts/problems discussed in the three groups of ECs, relating to the agricultural sector, to the expected risks to Egypt due to the GERD, and problems/conflicts at the national level.

As seen in Table 29, the ECs not only verified and validated the problems and conflicts of critical RCs and UDEs discovered earlier from the CRT and Cond. RT, but they also revealed solutions for these UDEs. These UDEs stemmed from the current situation of the Egyptian agricultural sector in general and in light of the expected risks to Egypt's water supply due to the GERD. The injections that appear to be most promising will be used in FRTs (next) and are shown in bold.

EC	Main objective	UDE	Injections (suggested solutions)
1	Ensure sufficient crops.	UDE59: The Egyptian production of crops decreases.	Egypt can ensure the efficiency/effectiveness of Egypt's agricultural management in the long term (B) AND maintain the same agricultural management plans (D') if: BD'1- **Use advanced water technologies and techniques to conserve water and reduce waste due to domestic and industrial activities** without changing agricultural practices; BD'2- **Apply the new plans gradually** or for specific agricultural lands. Egypt can have the same crops in the short term (C) AND change the agricultural management practices and plans (D) if: CD1- Import crops from international markets; CD2- Grow crops elsewhere out of Egypt by renting lands in other countries; CD3- Use different methods that use water and land more efficiently to produce the same crops.

EC	Main objective	UDE	Injections (suggested solutions)
2	Sustainable water supply to meet Egypt's needs.	UDE1: Egyptian water consumption is increasing.	Egypt can maintain an adequate volume of water (B) AND rely on the Nile only (D') if: BD'1- Sign an international agreement with Ethiopia; BD'2- Reduce water consumption. Egypt can have reasonable costs for the water supply (C) AND utilise different water sources than the Nile (D) by: CD1- **Getting funds through international entities.**
3	Display strong political will, support, vision, and leaders to support the agricultural sector by the Egyptian government.	UDE37: Egypt experiences widespread long-standing corruption and bribery. UDE27: Egypt has an ineffective governmental institutional framework and structure. UDE38: Laws are not enforced in Egypt.	Egypt can reduce corruption and bribery (B) AND stay with the same governmental institutional structure and laws (D') if: BD'1- **Improve the education facilities** to increase public awareness about corruption and bribery and their serious effects on the whole country. Egypt can minimise disruption to Egyptian performance (C) AND implement effective/efficient governmental institutional structure and laws (D) if: CD1- **Make the required changes in the governmental institutional structure and laws gradually**; CD2- **Engage the small stakeholders,** so there will be no resistance to change.
4	Improve the Egyptian agricultural sector.	UDE49: Egypt uses ineffective/inefficient agricultural management practices.	Egypt can maximise the benefits of the use of the land/water unit in the long term (B) AND use the same agricultural management plans (D') if: BD'1- **Eliminate the fragmentation of the landholding**, which reduces the productivity of both land and water. Egypt can avoid harming the agricultural and agro-industry sectors' performance in the short term (C) AND institute new/better agricultural management plans (D) if: CD1- Import the required quantities of crops for agro-industries; CD2- Make a slow and gradual change between the old plans and the new ones.

EC	Main objective	UDE	Injections (suggested solutions)
5	Maintain Egyptian electricity production.	UDE19: The efficiency of the hydropower generation share is not ensured. UDE20: The Egyptian electricity production is insufficient.	Egypt can ensure the success of the Egyptian electricity management (B) AND reduce the share of hydroelectricity in total Egyptian electricity production (D') if: BD'1- **Find new alternatives to generate electricity;** BD'2- **Buy electricity from other countries.** Egypt can ensure the efficiency of the electricity generation system (C) AND maintain the share of hydroelectricity in total Egyptian electricity production (D) if: CD1- Adopt new plans gradually; CD2- Use other renewable energy sources to generate electricity to be consumed or sold to other countries.
6	Maintain employment rate in the agricultural and agro-industries sectors.	UDE76: The unemployment rate increases.	Egypt can avoid increasing the unemployment rate (B) AND use different plans in the two sectors (D') if: BD'1- **Reallocate the workers/labourers** to other suitable positions; BD'2- **Open new markets** that could be suitable for these workers' experience; BD'3- Establish new employment opportunities. Egypt can ensure sufficient trained workers for the new jobs (C) AND continue using the same plans in the two sectors (D) if: CD1- Import the required raw materials/crops so the workers continue working in the same fields/factories, while **offering training that can gradually change their set of skills.**
7	Maintain the viability of the agro-industry system.	UDE32; The agro-industry is seriously impacted.	Egypt can maintain the continuity of agro-industry production in the short term (B) AND change the crop production (D') if: BD'1- **Import the required raw materials/crops** so the workers continue working in the same fields/factories, BD'2- **Grow crops somewhere** out of Egypt by renting lands in other countries. Egypt can ensure the long-term viability of the agro-industry sector (C) and keep the current Egyptian crops (D) if: CD1- Apply new policies to make gradual changes to the sector.

EC	Main objective	UDE	Injections (suggested solutions)
8	Minimise the risks and effects of the GERD construction on Egypt.	UDE75: The negative impact on the Egyptian economy is massive.	Egypt can avoid Egyptian governmental performance disruption (B) AND have new plans for the affected sectors (D') if: BD'1- **Apply the new plans gradually to avoid the Egyptian performance disruption;** BD'2- Provide workers with adequate training to avoid the Egyptian performance disruption. Egypt can avoid Egyptian economic failure (C) AND have no system change for the affected sectors (D) if: CD1- Open new markets for other sectors to avoid Egyptian economic failure; CD2- Encourage foreign investments in new sectors.
9	Maintain Egyptian economic performance.	UDE79: Poverty rate increases.	Egypt can maintain the continuity of economic activities on the short term (B) AND reduce the water obtained from the Nile (D') if: BD'1- Depend on other water resource alternatives to maintain the continuity of economic activities on the short term; BD'2- **Change the used technologies and techniques to decrease water consumption and reduce waste.** Egypt can ensure the resilience of the Egyptian economy on the long term (C) AND have the same amount of the Nile water (D) if: CD1- Apply new economic activities to maximise the Egyptian economic performance; CD2- Adopt a new Egyptian vision to change the Egyptian behaviours to reduce water consumption so it could be stored for later use.
10	Maintain public health.	UDE81: Public health deteriorates.	Egypt can have the same water quality (B) AND accepts Ethiopia continuing to fill the GERD (D') if: BD'1- Ethiopia fills the reservoir over a long period of time; BD'2- **Ethiopia pays for the treatment required for the Egyptian water.** Egypt can maintain the Egyptian-Ethiopian relationship (C) AND Egypt must stop Ethiopia from filling the GERD (D) if: CD1- Egypt compensates Ethiopia for the losses incurred by not operating the GERD; CD2- Egypt sells cheap electricity to Ethiopia.

EC	Main objective	UDE	Injections (suggested solutions)
11	Control social/civil unrest and reduce the crime rate.	UDE78: The crime rate increases. UDE80: Instances of civil unrest with violence steadily increase.	Egypt can ensure social stability (B) AND make a change in the sectors and numbers of jobs (D') if: BD'1- **Adopt resilient new economic plans to make the change gradually on the long-time term;** BD'2- Provide suitable training to workers to prepare them for the new jobs. Egypt can ensure economic stability (C) AND maintain the same sectors and numbers of jobs (D) if: CD1- Import required materials/crops to maintain the current jobs; CD2- Open new markets to ensure the availability of enough jobs.
12	Maximise the well-being of Egyptians.	UDE82: Egyptian welfare is seriously impacted.	Egypt can avoid Egyptian financial bankruptcy (B) AND continue using the current management and decision-making techniques (D') if: BD'1- Take out an international loan to avoid the Egyptian system's financial bankruptcy; BD'2- Sell some Egyptian assets. Egypt can maintain the stability of the government's managerial performance (C) AND apply new management and decision-making techniques (D) if: CD1- **Apply new plans gradually to avoid undermining the Egyptian government's performance;** CD2- **Engage citizens in the political process and raise awareness using the media to avoid disturbing the managerial performance of the Egyptian government.**
13	Ensure Egypt's survival.	UDE83: Egypt's chance of survival is impossible.	Egypt can maintain its economic performance and welfare (B) And reduce the Egyptian water share from the Nile (D') if: BD'1- Buy water from other countries; BD'2- **Find additional water sources** (e.g., Nubian aquifer); BD'3 - Become more efficient in using water. Egypt can maintain good international relationships with the neighbouring countries (C) AND maintain the Egyptian share of the Nile water (D) if: CD1- Neighbouring countries recognise Egypt's historical rights and **sign an international agreement with the other countries regarding how to manage the Nile as a shared watercourse;** CD2- Egypt pays for the damage that will occur to the other countries.

Table 29: Main objective, UDEs, and injections for the ECs.

Some of the key assumptions and possible injections for ECs 2-13 are provided in Appendix (B).

It is interesting to note that the EC found solutions that were "ideas out of the box". The EC is a powerful tool that turns an unacceptable compromise situation into a win-win situation, by clearly depicting why the conflict exists, and then rephrasing the conflict as "the situation is impossible unless …". Let us take EC5 as an example. The issue raised by the EC was "how to maintain the Egyptian electricity production". In this case, one assumption was that the efficiency of the Egyptian electricity generation system depends on the resilience of other energy alternatives. The EC greatly clarified the reason why the problematic situation exists because of the expected loss in hydropower generation due to the decrease of the water level at the AHD.

By following the EC process, ideas to evaporate the dilemma came to light. The EC helped me to understand the system better and reflect on how I can effectively solve the problem by seeing the two sides of the situation. The proposed ideas (injections) of the EC here were as follows:

- We can ensure the success of the Egyptian electricity management (B) and reduce the share of hydroelectricity in total Egyptian electricity production (D') at the same time if we:
  1- Find new alternatives to generate electricity.
  2- Buy electricity from other countries.
- We can ensure the efficiency of the electricity generation system (C) and maintain the share of hydroelectricity in total Egyptian electricity production (D) if we:
  1- Adopt new plans gradually.
  2- Use other renewable energy sources to generate electricity to be consumed or sold to other countries.

The new ideas (injections) expanded considerably on the options within Egypt's span of control and sphere of influence and made me think more about the direction of change. All proposed injections are ideas to resolve the dilemma by breaking one of the assumptions. However, they do not all have to be enacted to break an EC.

However, it is worth mentioning that in some cases more than one injection per EC was used in FRTs. There are three reasons for this. Firstly, the complex situation in Egypt needs some short-term solutions and others that focus on the long term. For instance, Egypt cannot depend on importing crops to supply its needs forever. This could be a short-term plan to ensure the continuity of the agro-industries. However, there is a need to grow crops elsewhere for a long-term solution. Two injections were used from EC7 here.

Secondly, Egypt has a population of 103 million, thereby further complicating the situation. In some cases, one injection will not be sufficient and effective to ensure the complete elimination of any further negative side effects expected from implementing the solutions that were suggested. For example, as was previously explained, over 25% of the Egyptian population is working in agro-industries, while about another 30% is directly working in farming. About 55 million people work in agricultural and agro-based activities (FAO, 2019). An increase in the unemployment rate is expected due to the losses of Egyptian agricultural lands due to the GERD. Using one injection from EC6 alone is not sufficient to eliminate any further negative side effects. Three injections were used to effectively manage the side effects, first to reallocate the workers, second to open new markets, and third to offer them training that can gradually change their set of skills. The used injections were all necessary and needed to address potential NBR's that would have arisen.

Thirdly, in the next step of the TP process, the most promising solutions are tested in the FRT. The injections suggested by the EC analyses to break each EC and turn the UDEs into desirable ones were used to build three different FRTs, each constructed for different reasons.

7.2.4. Future Reality Tree (FRT) analysis and findings

Data for the FRTs was collected using interview questions 13-14 (Appendix A), which asked the participants about the benefits and negative side effects of their proposed solutions. These questions were as shown below:

13) If your recommended solution were implemented, what benefits would you expect to see as a result of these actions?
14) Do you foresee any negative side effects if this solution was in place?

The FRT is a logical tool that shows the effects of implementing a proposed solution (Dettmer, 2007). Building on the ECs, FRTs were used to continue answering the third question "What to change to?". Three big FRTs were created to answer this question.

FRT1 answers the question regarding the current situation of the Egyptian agricultural sector, while the second and third FRTs answer the question in light of the expected risks to Egypt's water supply due to the GERD through two different scenarios. The first scenario (FRT2) assumes that Egypt will succeed in having an agreement with Ethiopia to fill the GERD's reservoir slowly, which will not affect the Egyptian Nile's water share. The second scenario (FRT3) assumes that the negotiations between the two countries will fail, and Egypt will have to find other water resource alternatives.

The injections used in the FRTs draw heavily on the participants' answers. However, these answers were not used directly as injections. The answers to the two previous questions along with the ECs' injections provided ideas that were clustered to form the injections for the FRTs. The process started with the first step in the consolidation of the recommended solutions into groups. The first group used for FRT1 related to the recommended solutions to improve the Egyptian agricultural sector in general (without taking into consideration the GERD), which was one of the main goals discussed in the GTs earlier. Other ideas and answers were used in FRT2 and FRT3 in the case of the GERD to serve the main goal of the GT, "Ensure Egypt's survival".

7.2.4.1. The first FRT1: Ensure the Egyptian agricultural sector's success

FRT1 tests the new policies, measurements and procedures that are required to ensure the future success of the Egyptian agricultural sector. The FRT is read from bottom to top using sufficient cause thinking, such as in the CRT, to check that the expected results match the desires. The proposed injections/solutions that the tree starts with are 16 main solutions. These injections could be clustered into two groups.

The first group includes injections concerned with water and agricultural practices as follows:

- Inj15: Egypt uses advanced water technologies and techniques to conserve water and reduce waste.
- Inj16: Egypt changes the agricultural management practices and plans. Examples of these changes include no longer growing water-intensive crops and changing the crop yield map.
- Inj4: The government engages stakeholders in the required changes, so they do not resist the changes.
- Inj1: The government enables consolidation of small and fragmented agricultural holdings by establishing agricultural cooperatives and associations managed by one person on behalf of the landholders in their cooperative.
- Inj9: The government finds other water resource alternatives at reasonable costs.
- Inj10: Costs of water resource alternatives are funded by international funds and entities (WB).

The second group includes the injections concerned with the government's performance as follows:

- Inj8: The government raises awareness regarding the climate change problem and takes actions to slow its consequences.
- Inj6: The government provides access to family planning and modern contraceptive methods to control population growth. For example, the government includes the costs of modern contraceptive methods in the public health insurance scheme.
- Inj5: The government provides managers, professionals, and farmers with adequate training programmes.
- Inj14: Effective/efficient economic plans for different sectors are instituted to reduce water consumption.
- Inj12: Egypt changes its national economic policies and plans (to force a shift to new activities).
- Inj11: The government raises public awareness regarding unhelpful habits, traditions, and practices to reduce water waste.
- Inj7: The government improves the public education system and curriculum to decrease the public's water consumption.
- Inj3: The government implements effective changes in the agricultural sector. Examples of these changes include changing governmental institutional structures, funds, and laws, and implementing this gradually to minimise disruption to Egyptian performance.
- Inj2: The government increases public awareness about corruption and bribery and their serious effects and ensures the coverage and support of the media.
- Inj13: The government ensures that the values of democracy and transparency govern Egyptian policies.

FRT1 is divided into four subordinate FRTs that show different injections that result in turning the UDEs into DEs of the studied system, as shown in Figures 41, 42, 43, and 44. Off-page connectors are used to indicate arrows between entities that appear on adjacent FRT diagrams, where a number in a circle indicates the entity that appears on another FRT.

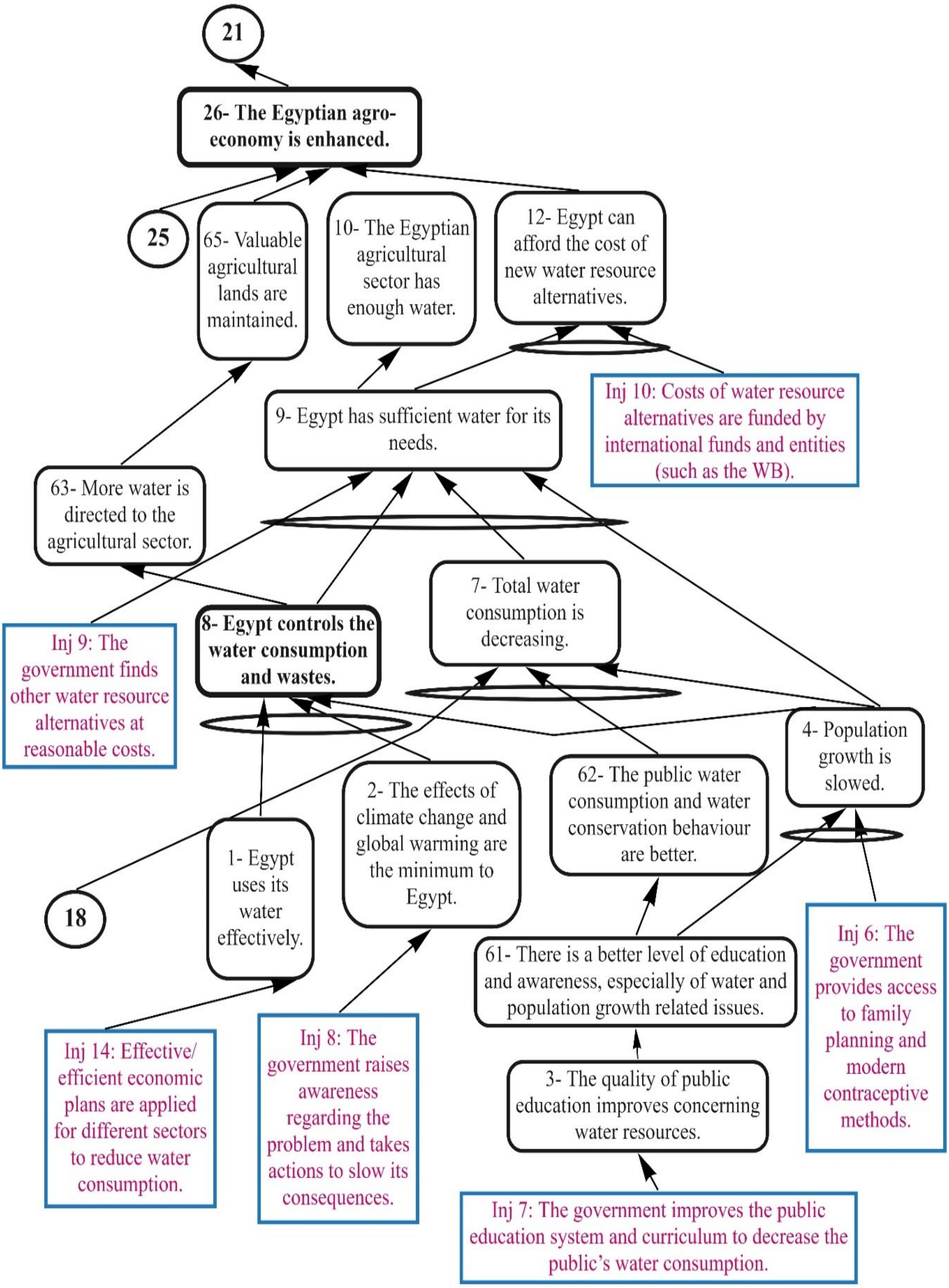

Figure 41: FRT 1.1.

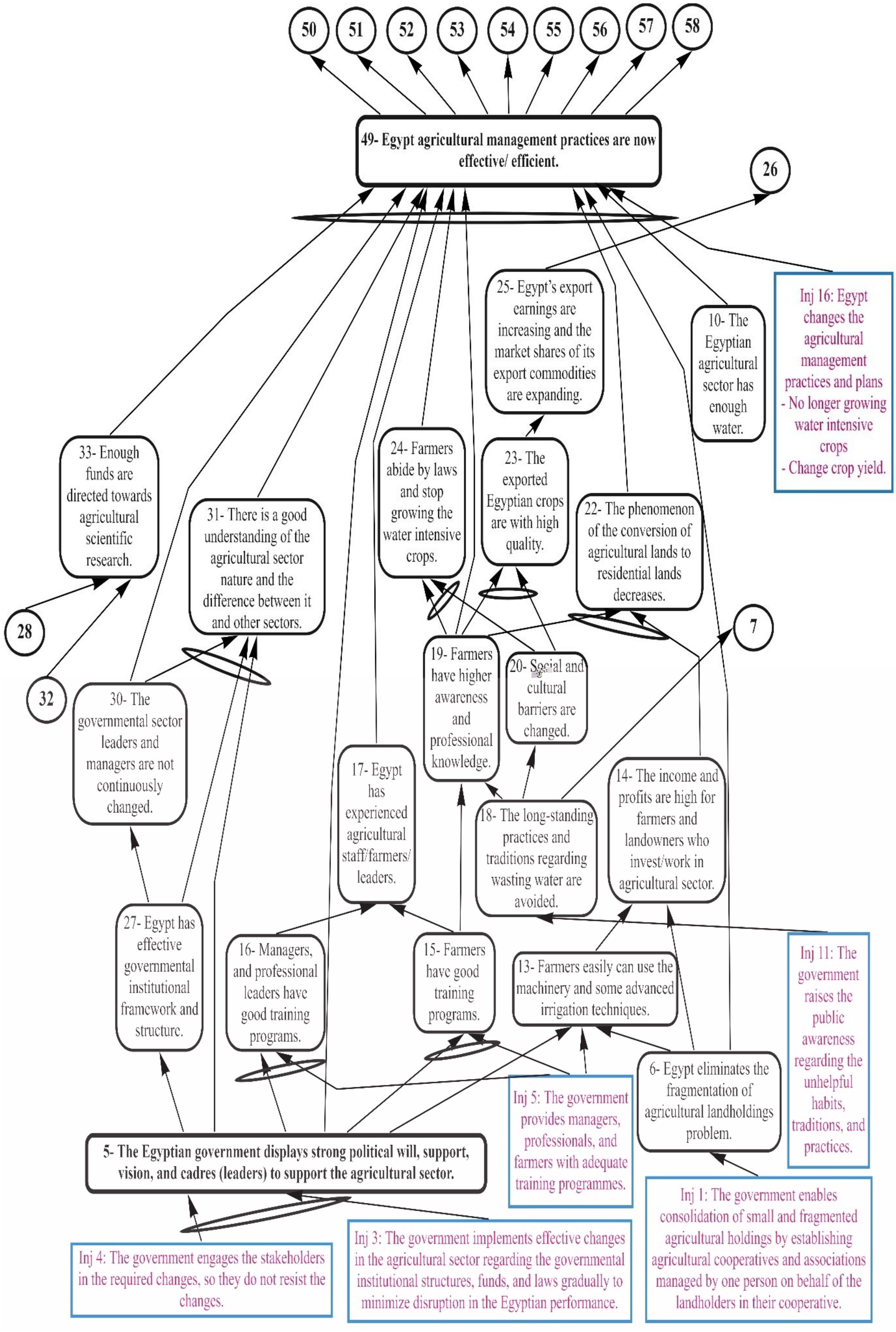

Figure 42: FRT 1.2.

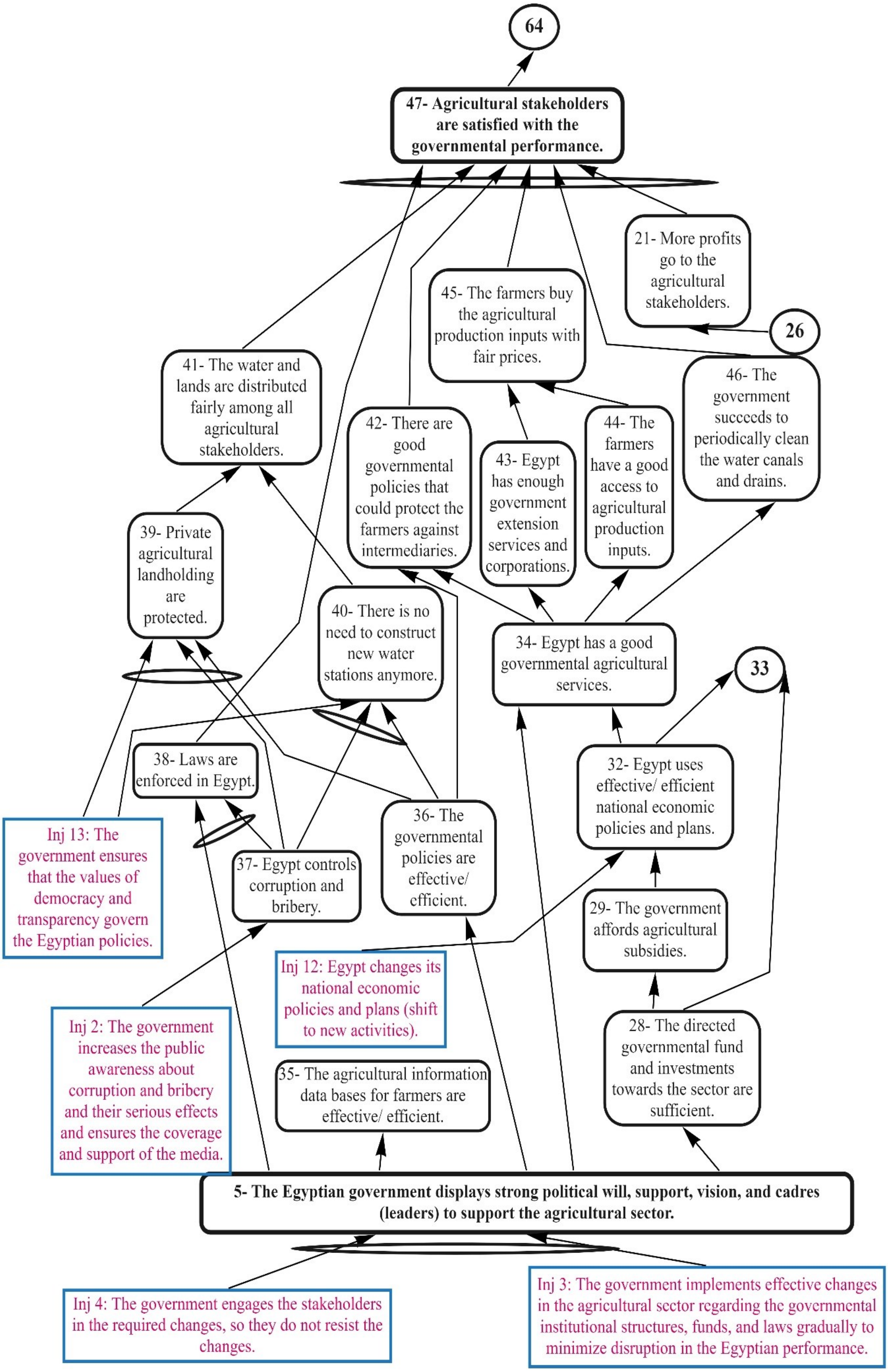

Figure 43: FRT 1.3.

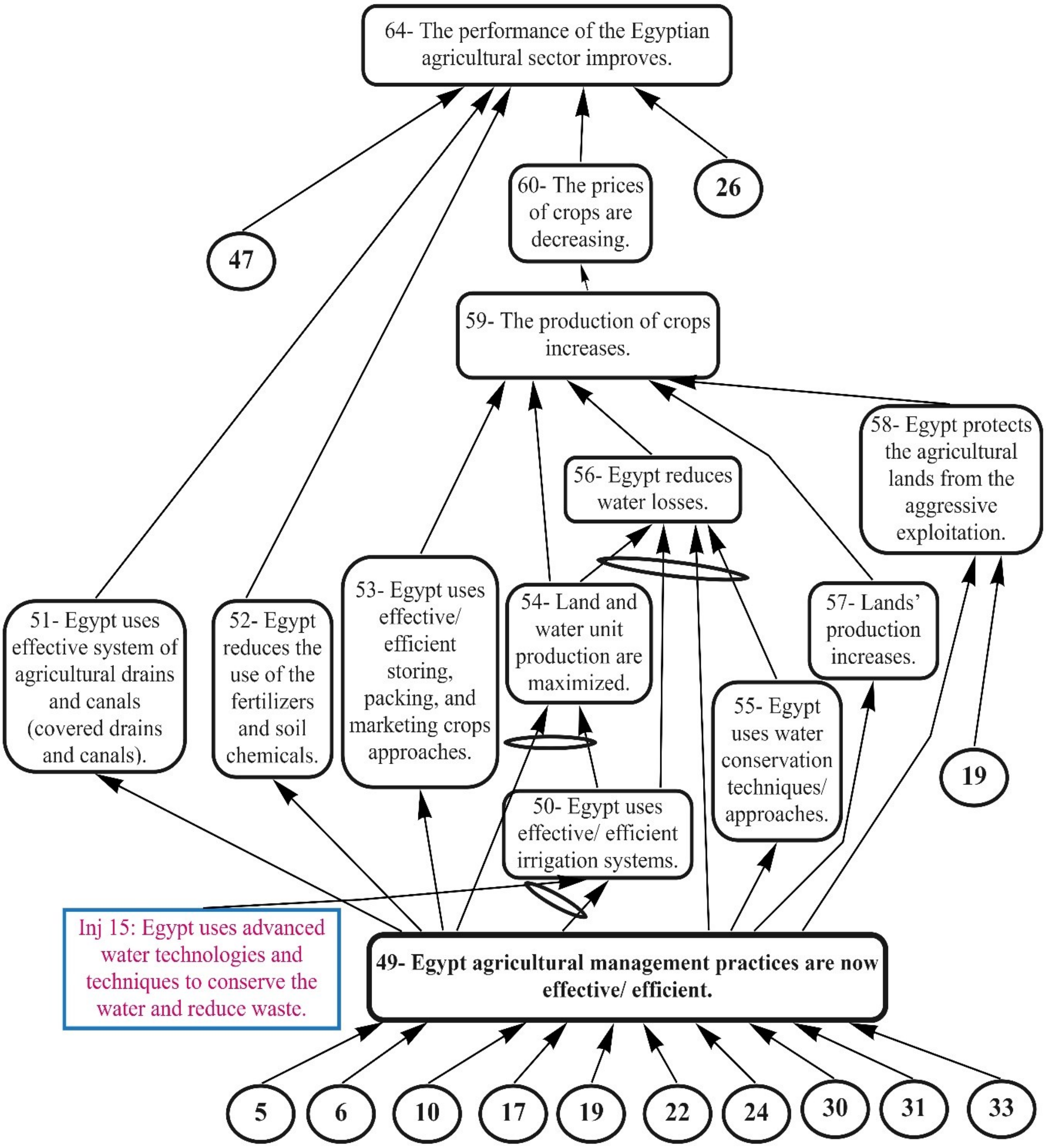

Figure 44: FRT 1.4.

Commentary on participants' remarks

All participants indicated that there were no further negative side effects expected from implementing the solutions they were suggesting.

Participant NL1 commented that one of the effective/efficient agricultural management practices is **covered pipes** for water canals and drainage canals instead of open ones. He added, "Using covered pipes will allow farmers to plant over the pipes' areas. That will increase the agricultural lands by four karats[6] per acre." And of course, they will reduce water evaporation.

[6] Karat is a unit of land measurement. One karat is equivalent to 1/24 (0.041) of an acre.

Participant IL10 discussed greenhouse technology as one of the effective/ efficient agricultural management practices. In the same context, he also discussed changing the old flood irrigation technique to drip, sprinkler, and pivot irrigation techniques. He explained that governmental incentives could be good motivation to overcome people's resistance to change; he said, "**Governmental financial support** and **concessional bank loans** for small landowners could be so tempting to make them change their irrigation systems and adopt the greenhouse technology".

Participant LL8/IL11 discussed the need for a wider use of **scientific research** to develop new strains of low water-intensive crops.

Participant NL7 claimed that Egypt should implement different water reduction strategies, such as importing (rather than growing) water-intensive crops, rationalising water consumption and reducing water losses, and applying different water conservation techniques. He added, "Water is now a strategic target."

7.2.4.2. The second and third FRTs: An analysis of the situation due to the GERD

The second and third FRTs answer the question in light of the expected risks to Egypt's water supply due to the GERD through two different scenarios. The first scenario (FRT2) assumes that Egypt will succeed in having an agreement with Ethiopia to fill the GERD's reservoir slowly, which will not affect the Egyptian Nile's water share. The second scenario (FRT3) assumes that the negotiations between the two countries will fail, and Egypt will have to find other water resource alternatives.

7.2.4.2.1. FRT2: Scenario 1- Assuming a bilateral Egyptian-Ethiopian agreement

FRT2 presents the forecasted picture of "What to change to" considering the expected risks to Egypt's water supply due to the GERD in the near future. The underlying assumption, in this case, is an Egyptian-Ethiopian bilateral agreement that regulates the rules of the filling and operating process of the GERD such that this happens at a slow pace. A slow pace is defined as the withdrawal of less than 15% of the Nile's flow annually. This slow pace would not affect the Egyptian Nile water share much. However, FRT1 acts as a subordinate tree for FRT2. FRT1 represents the expected results that match the desires regarding the current situation of the Egyptian agricultural sector, which should be a part of the solution.

The FRT is read from bottom to top using sufficient cause thinking to check what happens if the potential solutions, gained from analysing the participants' answers and breaking the ECs, are implemented. The proposed injections/solutions that the tree starts with are three main solutions as follows:

- Inj1: Government raises awareness regarding the environmental degradation problem and acts to slow its consequences.
- Inj2: Egypt has an agreement with Ethiopia to fill the GERD over a very long timeframe, which will not affect the water's quantity or quality.

- Inj3: The government provides access to family planning and modern contraceptive methods.

As can be seen, this tree is predicated on the success of the Egyptian-Ethiopian negotiations, while FRT1 is included in the red circle with its 16 injections that cover the agricultural sector. For this study, FRT2 was divided into four subordinate FRTs that show injections that result in turning the UDEs into DEs of the studied system as shown in Figures 45, 46, 47, and 48.

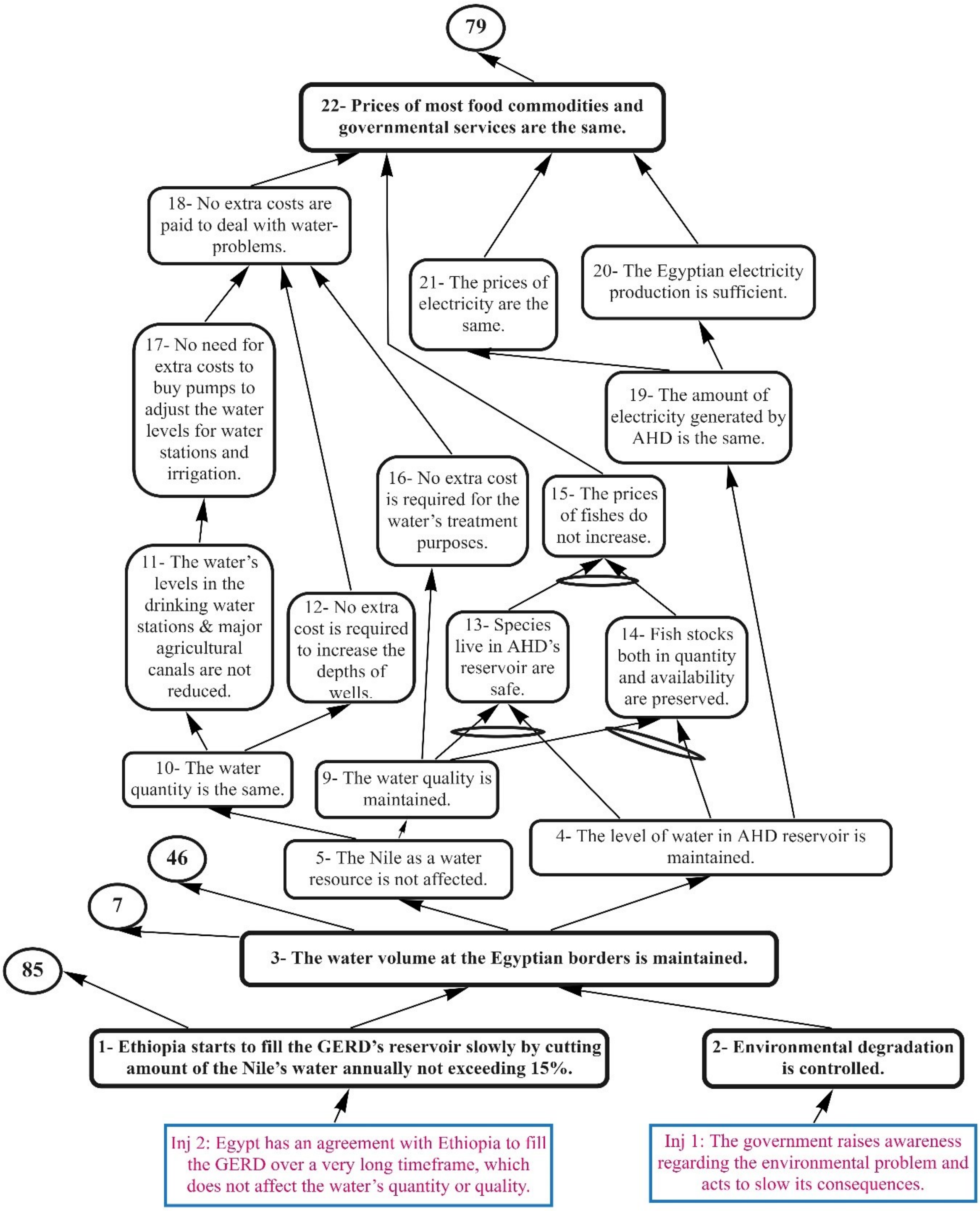

Figure 45: FRT 2.1.

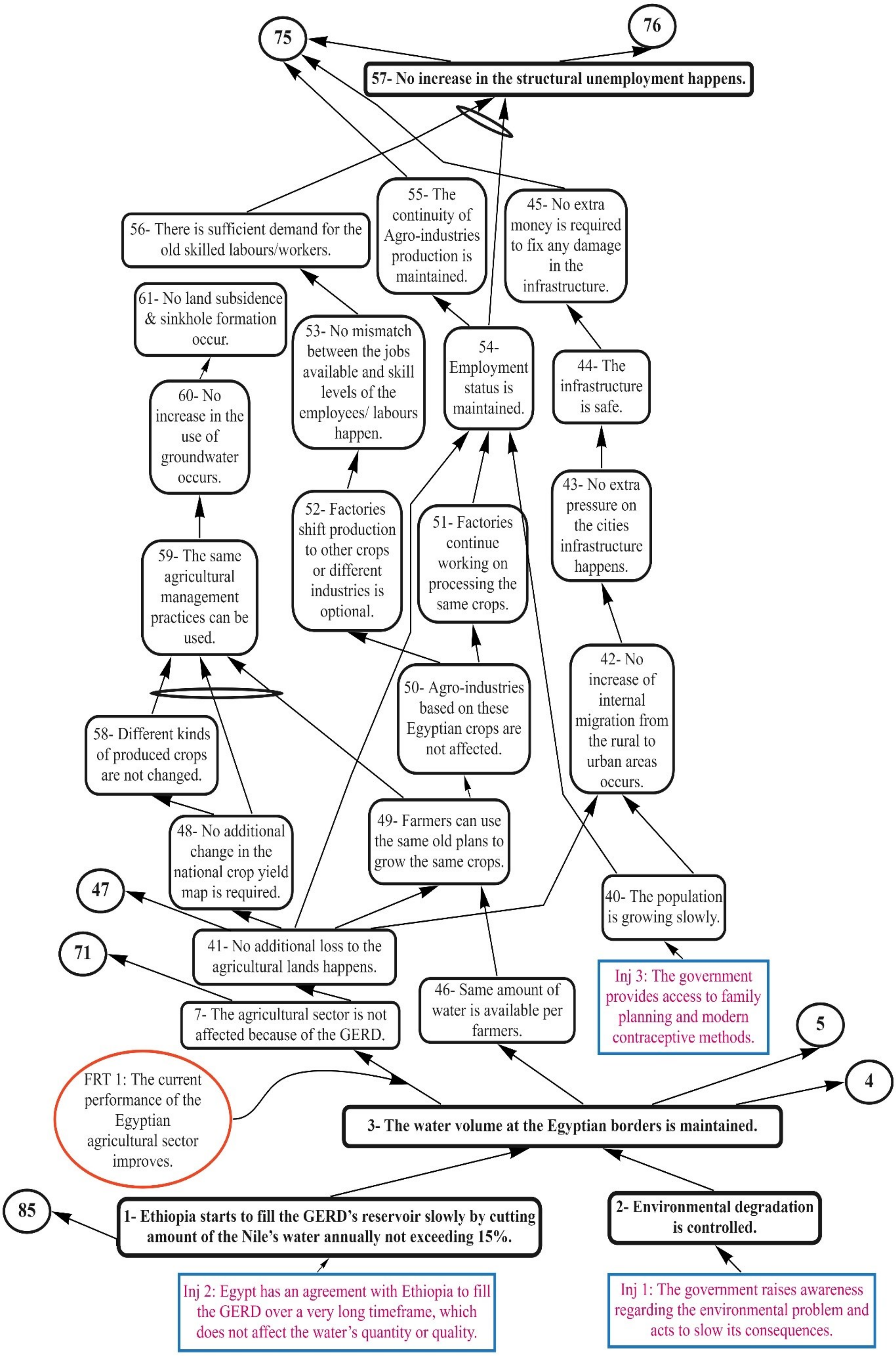

Figure 46: FRT 2.2.

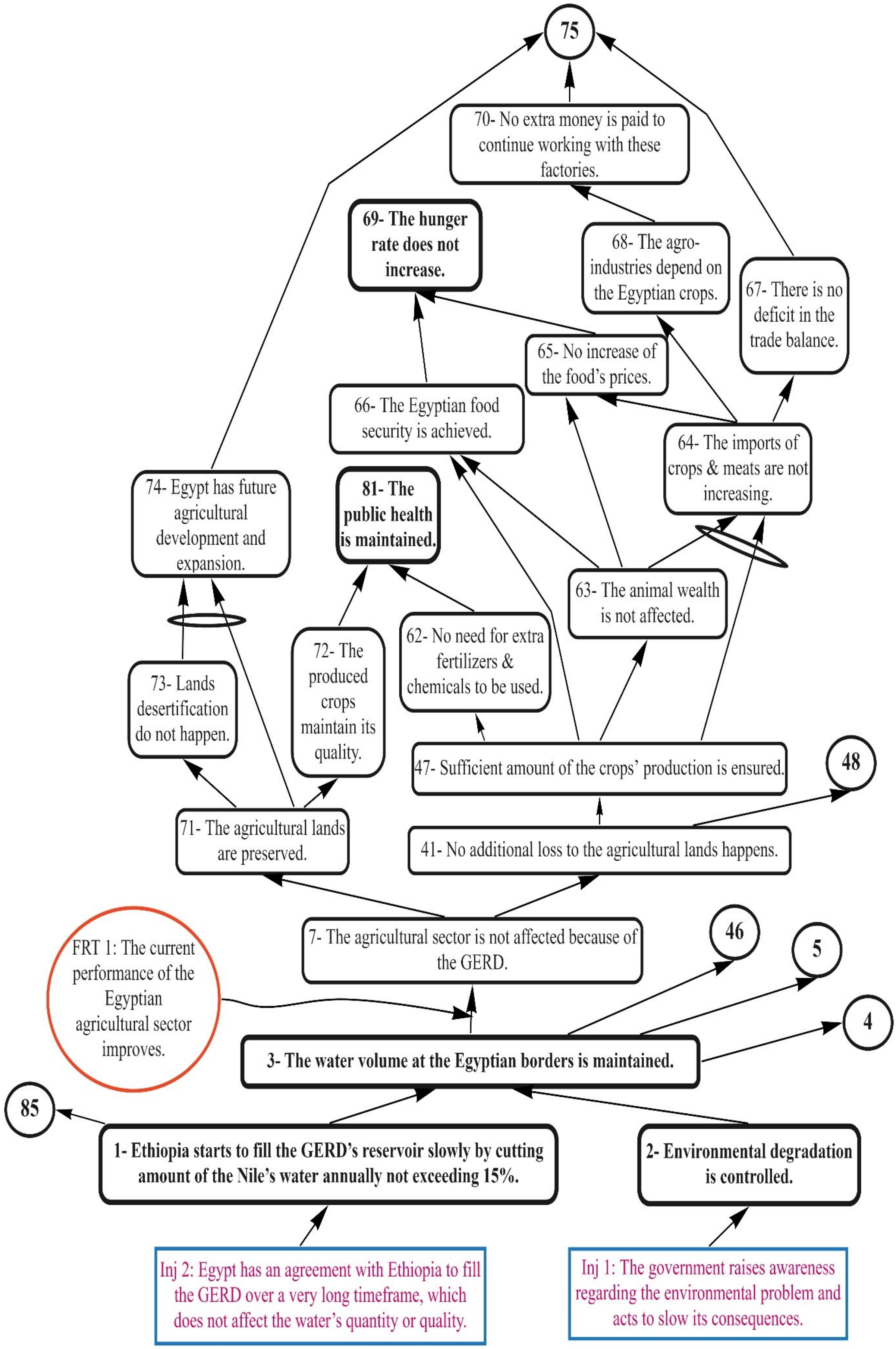

Figure 47: FRT 2.3.

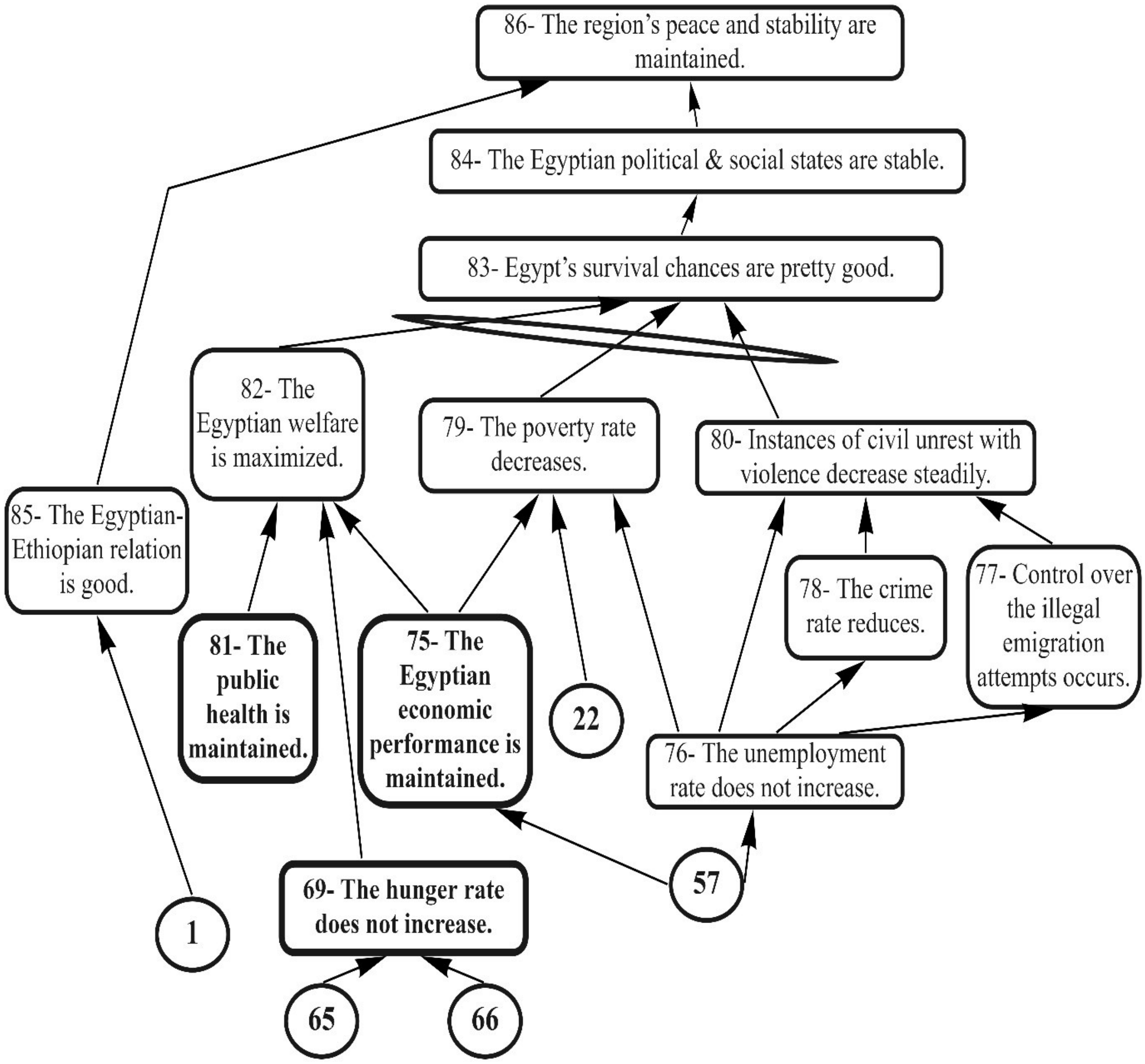

Figure 48: FRT 2.4.

7.2.4.2.2. FRT3: Scenario 2- Egypt must find other water resource alternatives

FRT3 presents the forecasted picture of "What to change to" considering the expected risks to Egypt's water supply due to the GERD in the near future. The main premise here, however, is the failure of bilateral negotiations and Egypt's need to find other water resource alternatives. However, FRT1 still acts as a subordinate tree causally linked to FRT3. FRT1 represented the expected results to construct and test potential solutions regarding the current UDEs of the Egyptian agricultural sector, which should be a part of the solution in any case.

The FRT is read from bottom to top using sufficient cause thinking to check that if the solutions, yielded from the analysis of the participants' answers and the application of the ECs, are implemented, then a desired future is achieved. The proposed injections/solutions that the tree starts with are 19 main solutions. These injections could be clustered into three groups.

The first group includes the injections concerned with mitigating the impacts of the GERD on the irrigation and agricultural sector as follows:

- Inj2: Egypt finds other water resource alternatives.
- Inj3: Egypt utilises different water resources with the Nile.
- Inj11: Ethiopia compensates/pays Egypt to fund new water resources.
- Inj12: Costs of water resource alternatives are funded by international funds and entities (WB).
- Inj8: Ethiopia is responsible for water treatment.
- Inj9: Ethiopia pays the required costs to buy pumps to adjust the water levels for water stations and irrigation.
- Inj10: Egypt reduces its national water consumption and waste.
- Inj14: Egypt carries out precautionary measures of the agricultural management plans due to the GERD.
- Inj15: Egypt maximises the benefits of each water unit by using effective/ efficient water technologies and techniques to conserve water and reduce waste.

The second group includes the injections concerned with mitigating the impacts of the GERD on electricity generation, agro-industries, and the increase of unemployment rate as follows:

- Inj5: Egypt uses other renewable energy sources to generate electricity (solar plants).
- Inj6: Ethiopia sells Egypt cheap electricity.
- Inj7: Egypt buys electricity from other countries.
- Inj16: Egypt imports the required crops from international markets.
- Inj4: Ethiopia pays Egypt for the damage caused by the decrease in water level in the AHD reservoir that will affect the species that live there and force Egypt to buy fish from elsewhere.
- Inj17: Egypt provides workers with the required training for the new jobs/ Or Egypt establishes new employment opportunities.
- Inj18: Egypt imports crops from international markets/ or grows crops elsewhere by renting lands in other countries to supply the factories.
- Inj19: Workers are reallocated to other suitable positions/ or Egypt opens new markets suited to the workers' experiences.

The third group includes the injections concerned about the government's general performance as follows:

- Inj1: The government raises awareness regarding the environmental degradation problem and takes actions to slow its consequences.
- Inj13: The government provides access to family planning and modern contraceptive methods to slow population growth.

FRT3 is divided into four subordinate FRTs that show injections that turn the UDEs into DEs as shown in Figures 49, 50, 51, and 52, while FRT1 is included in the red circle with its 16 injections focus on the agricultural sector.

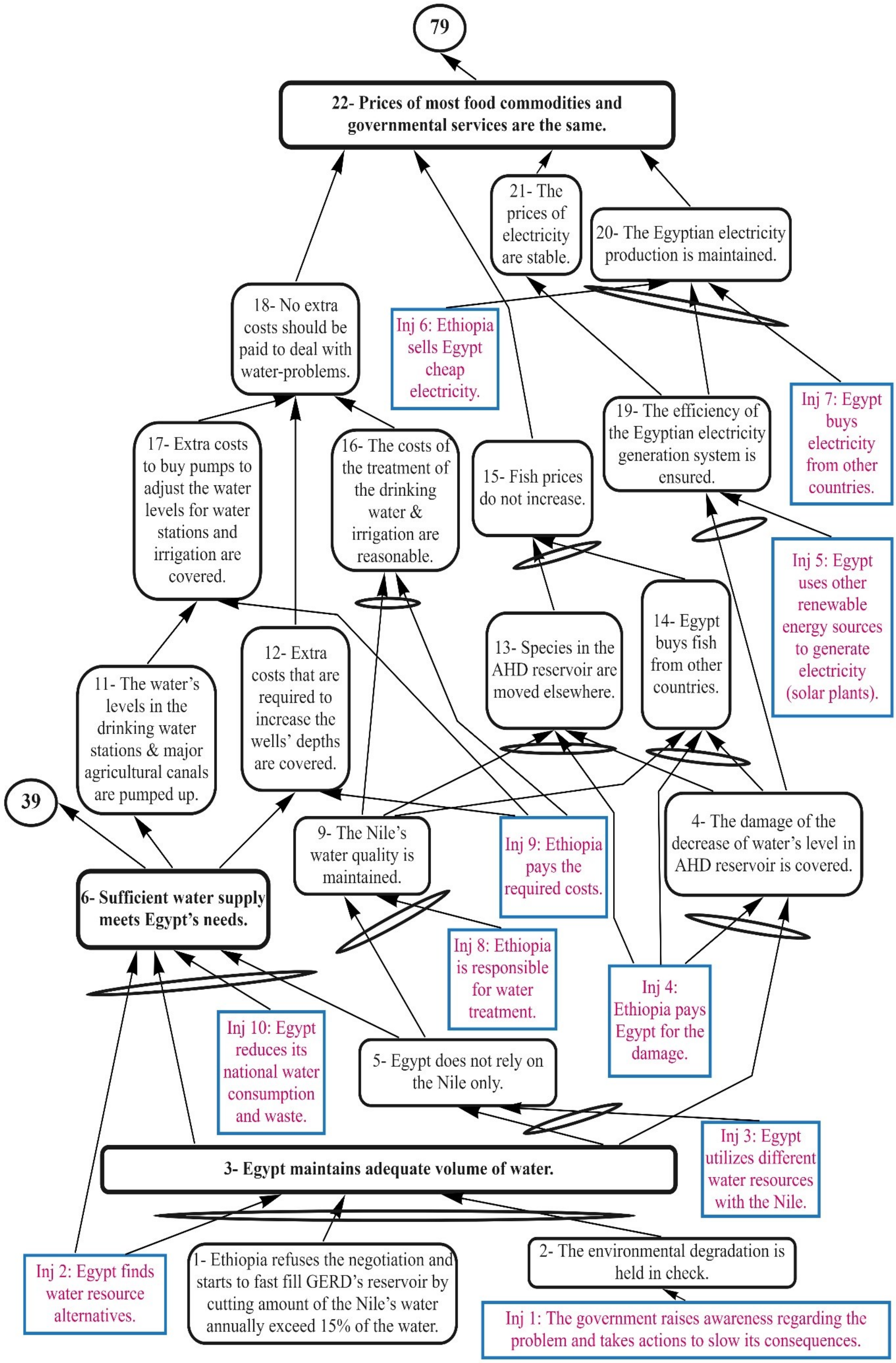

Figure 49: FRT 3.1.

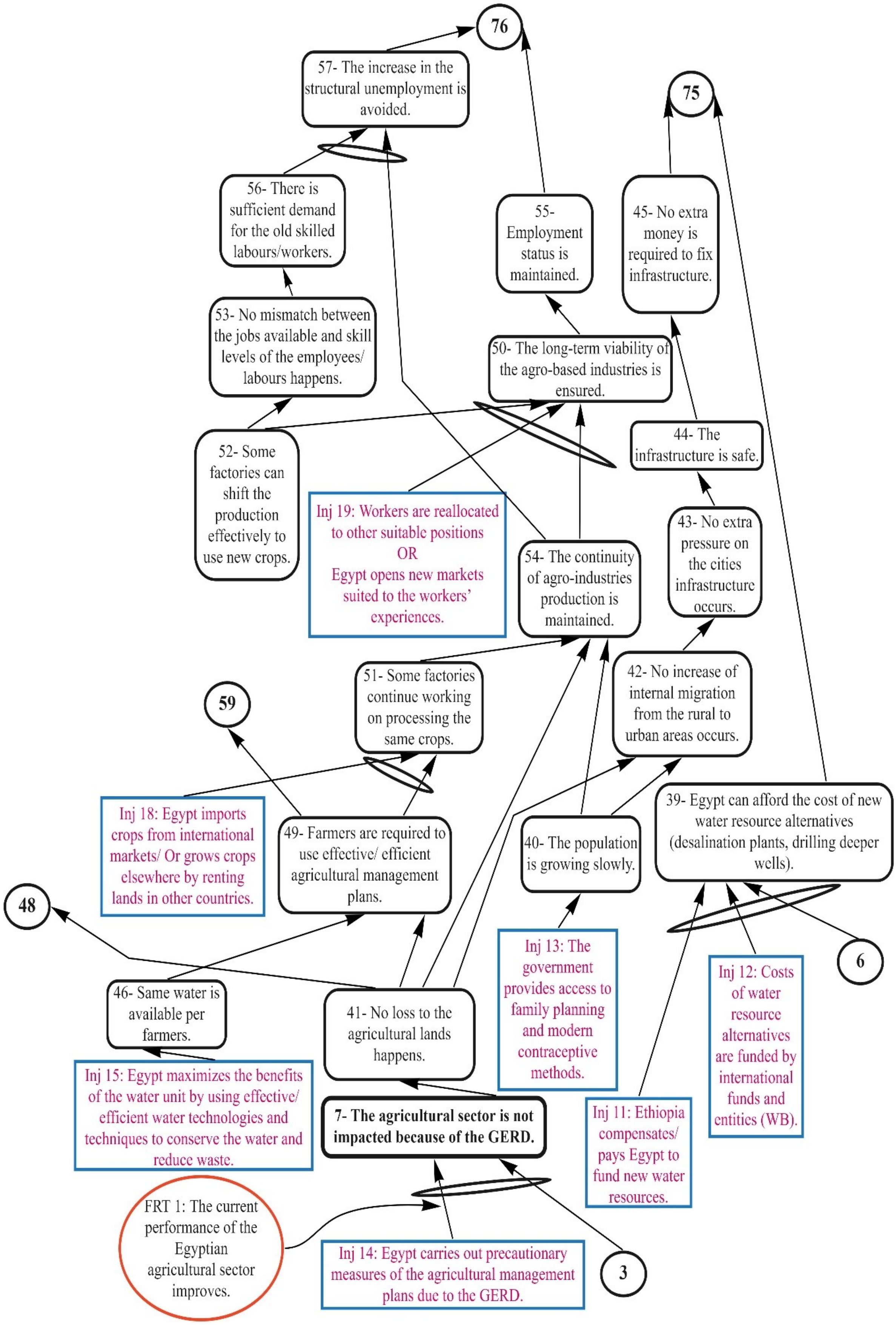

Figure 50: FRT 3.2.

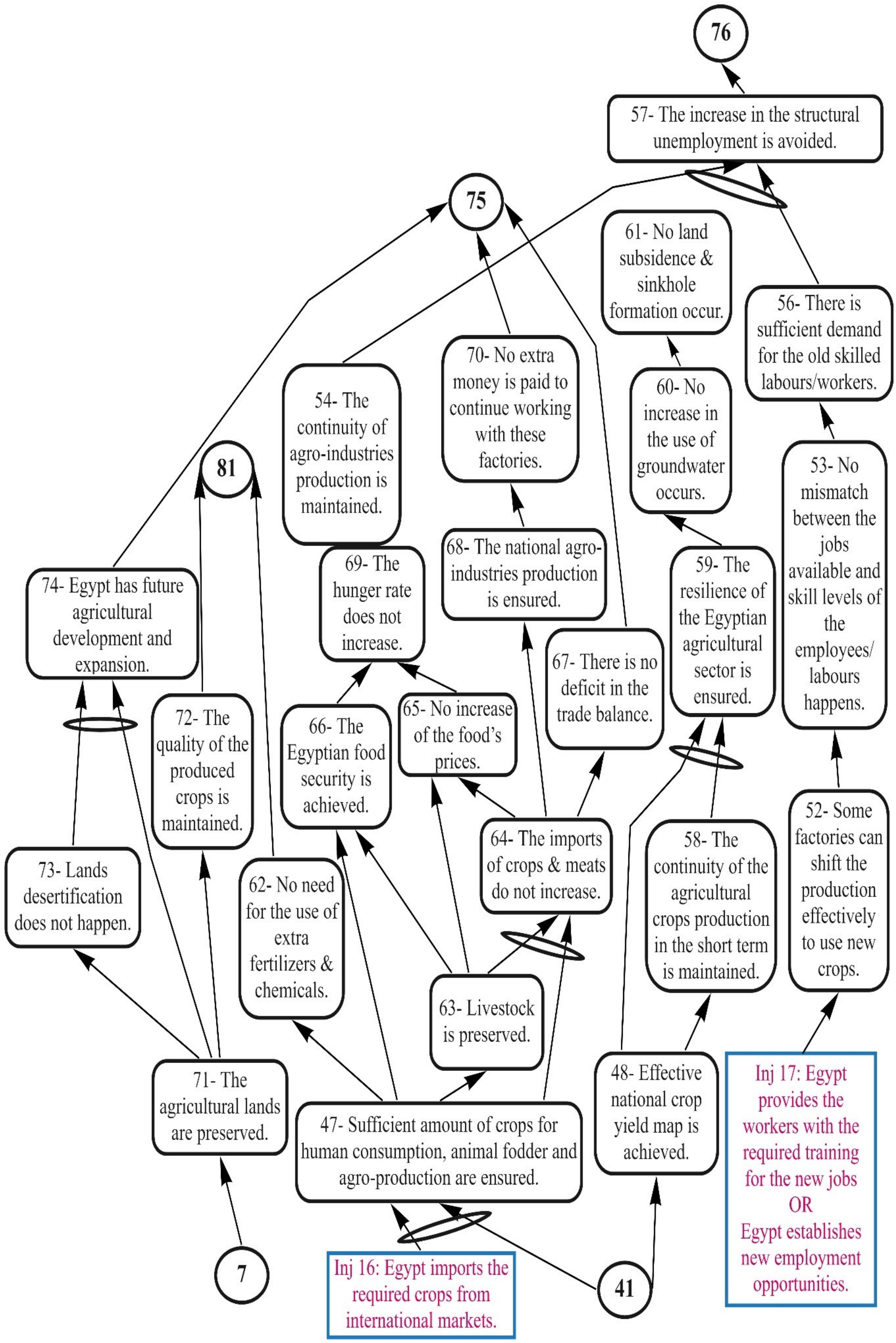

Figure 51: FRT 3.3.

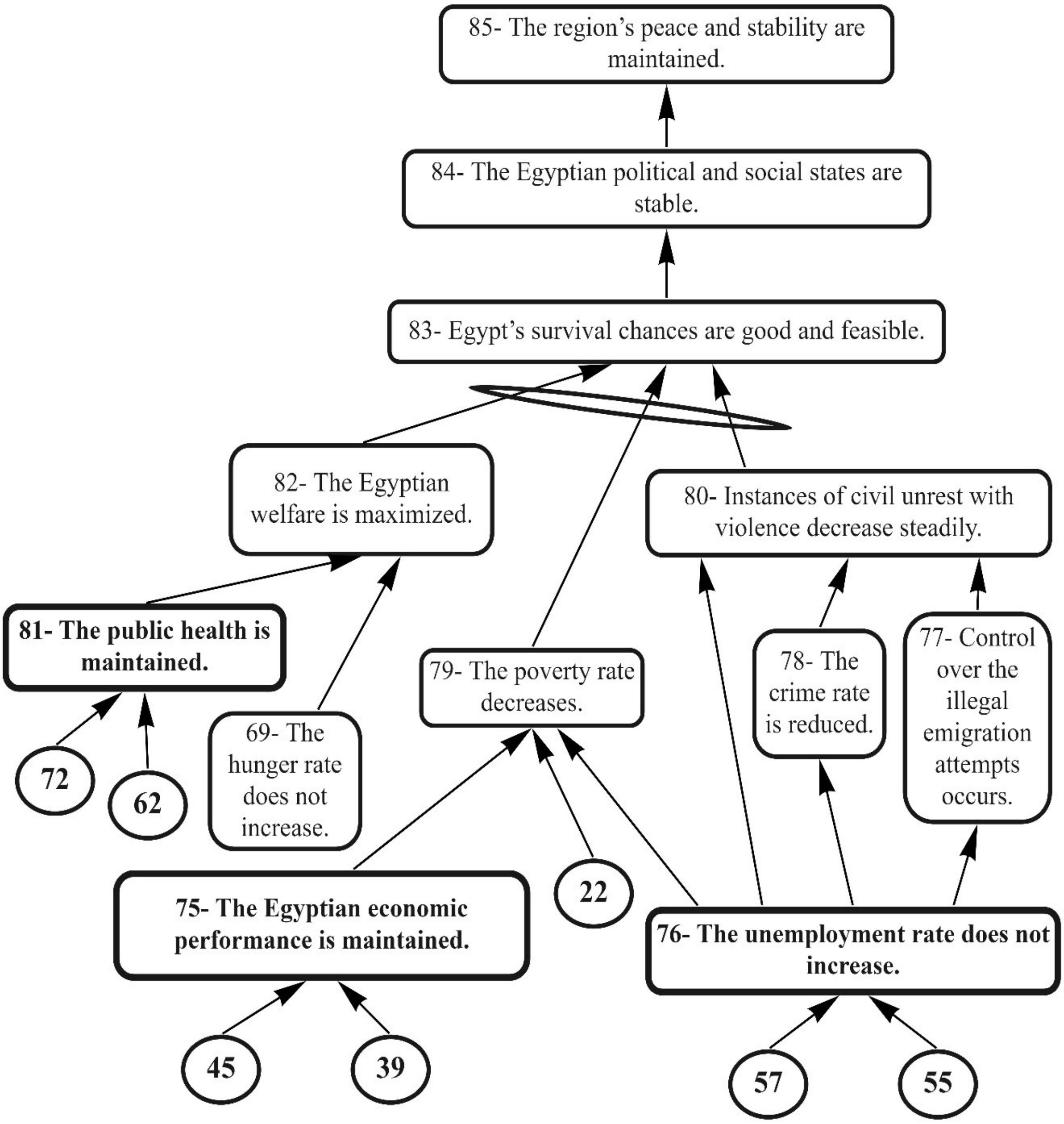

Figure 52: FRT 3.4.

<u>*Commentary on participants' remarks*</u>

All participants indicated that there are no further negative side effects expected from implementing the solutions they were suggesting for FRT2 and 3.

Participant NL3/LL1 claimed that Egypt needs to encourage investment in alternative economic activities, such as **small and medium enterprises** in the industrial sector, which in turn will accommodate the people that would lose their jobs in the agricultural sector.

Participant IL2 claimed that Egypt could use **indicative economic planning** instead of its current ineffective/ inefficient national economic policies and plans. He explained, "Indicative planning is a form of national economic planning that aims to increase national output over the long term. This type of planning avoids the imperfection of information related to market economies by using quantitative estimates, forecasts, and output targets. It is accompanied by a list of policy measures intended to help fulfil the plan. These measures could include incentives or disincentives (such as subsidies or taxes)". He added, "These incentives could also take the form of the government helping with marketing the crops or buying crops itself".

Participant LL2/IL7 suggested establishing a joint agricultural project in Sudan. He commented, "The benefit of that project is a good opportunity to resettle the Egyptian workers there in Sudan, especially with the rapid growth of the Egyptian population." He added that Egypt must seek to increase its **investments in Ethiopia** as well.

Participant LL4/IL7 agreed with participant LL2/IL7 about increasing Egyptian investments in Ethiopia as well. He confirmed the importance of the diplomatic solution. He commented, "Egypt must increase its investments in Ethiopia, and establish joint agricultural and livestock projects there. The production of these projects could be exported back to Egypt. Moreover, Egyptian workers can be resettled there."

Participant LL5/IL8 saw that one of the solutions regarding the Egyptian-Ethiopian dispute could be **escalating the problem to the United Nations** and even suggested taking action to damage the dam. He also suggested reducing the water losses into the Mediterranean Sea.

Participant LL6 argued that to a certain extent, Egypt could use some of **the water stored in AHD's reservoir** to cover the water shortages expected from the GERD. These suggestions will be considered further using the 5FS in Section 7.2.6.

<u>The findings of the FRTs</u>

Dettmer claims that the FRT builds on the CRT and the EC through the problem-solving process (Dettmer, 2007). Notice that the construction of the FRT was underpinned by the findings of the GTs, which provided the goals, the CSFs and NCs; the CRTs which identified the RCs and the UDEs; and the ECs that found possible solutions (injections) in order to turn the UDEs into DEs. The FRTs show how most of the proposed injections lead to the desired effects and the desired future. In this study, the current issues related to the Egyptian agricultural sector have first been mitigated by incorporating the needed injections to ensure that all UDEs turned to be desirable ones. Second, the risks to Egypt's water supply due to the GERD are mitigated by incorporating the needed injections to ensure that all effects are desirable at the top of the tree.

<u>The findings of FRT1</u>

FRT1 tests whether the proposed solutions will improve the status quo of the Egyptian agricultural sector and brings about the DEs without creating negative side effects. There were not any expected negative side effects of these solutions if implemented, as have been said by participants. Therefore, these FRTs in this study serve as a framework to change the future.

In summary, Table 30 shows the UDEs and the chosen injections that help to turn them into DEs.

UDEs	Injection/proposed solution	DEs
6- Egypt suffers from the fragmentation of agricultural landholdings.	Inj1: The government enables consolidation of small and fragmented agricultural holdings by establishing agricultural cooperatives and associations managed by one person on behalf of the landholders in their cooperative.	6- Egypt eliminates the problems arising from the fragmentation of agricultural landholdings.
37- Egypt experiences widespread, long-standing corruption and bribery.	Inj2: The government increases public awareness about corruption and bribery and their serious effects and ensures the coverage and support of the media.	37- Egypt controls corruption and bribery.
5- The Egyptian government displays a lack of political will, support, vision, and cadres (groups of leaders) to support the agricultural sector.	Inj3: The government implements effective changes in the agricultural sector regarding the governmental institutional structures, funds, and laws gradually to minimise disruption in the Egyptian performance.	5- The Egyptian government displays a strong political will, support, vision, and cadres (leaders) to support the agricultural sector.
	Inj4: The government engages the stakeholders in the required changes, so they would not resist the changes.	
15- Farmers lack good training programmes.	Inj5: The government provides managers, professionals, and farmers with adequate training programmes.	15- Farmers have good training programmes.
16- Managers, and professional leaders lack good training programmes.		16- Managers, and professional leaders have good training programmes.

UDEs	Injection/proposed solution	DEs
4- The population is growing rapidly.	Inj6: The government provides access to family planning and modern contraceptive methods.	4- The population is growing slowly.
3- The quality of public education has deteriorated, which affects the public water consumption.	Inj7: The government improves the public education system and curriculum to decrease the public water consumption.	3- The quality of public education improves concerning water resources.
2- Climate change and global warming are affecting Egypt.	Inj8: The government raises awareness regarding the problem and takes actions to slow its consequences.	2- The effects of climate change and global warming are the minimum for Egypt.
9- Egypt needs to find other water resource alternatives.	Inj9: The government finds other water resource alternatives at reasonable costs.	9- Egypt has sufficient water for its needs.
1- Egypt already suffers from water poverty.	Inj14: Effective/ efficient economic plans are applied for different sectors to reduce water consumption.	1- Egypt uses its water effectively.
12- Costs of water resource alternatives are very expensive.	Inj10: Costs of water resource alternatives are funded by international funds and entities (such as the WB).	12- Costs of water resource alternatives are bearable.
18- Many long-standing practices and traditions (cultural, behaviours) are wasting water.	Inj11: The government raises public awareness regarding unhelpful habits, traditions, and practices.	18- The long-standing practices and traditions regarding wasting water are avoided.
32- Egypt suffers from ineffective/ inefficient national economic policies and plans.	Inj12: Egypt changes its national economic policies and plans (shift to new activities).	32- Egypt uses effective/ efficient national economic policies and plans.
39- Private agricultural lands are expropriated by some of the national security agencies (for their own benefits).	Inj13: The government ensures that the values of democracy and transparency govern the Egyptian policies.	39- Private agricultural landholdings are protected.

UDEs	Injection/proposed solution	DEs
41- The water and lands are distributed unfairly in favour of the agricultural projects owned by the army and some of the national security agencies.		41- The water and lands are distributed fairly among all agricultural stakeholders.
50- Egypt uses ineffective/ inefficient irrigation systems.	Inj15: Egypt uses advanced water technologies and techniques to conserve water and reduce waste.	50- Egypt uses effective/ efficient irrigation systems.
49- Egypt suffers from ineffective/ inefficient agricultural management practices.	Inj16: Egypt must change its agricultural management practices and plans. - No longer growing water-intensive crops. - Change crop yield.	49- Egypt uses effective/ efficient agricultural management practices.

Table 30: The UDEs, injections and DEs of FRT1.

The complete FRT1 is represented in Figure 53. The complete diagram is segmented based on the subordinated FRTs as can be seen in the figure.

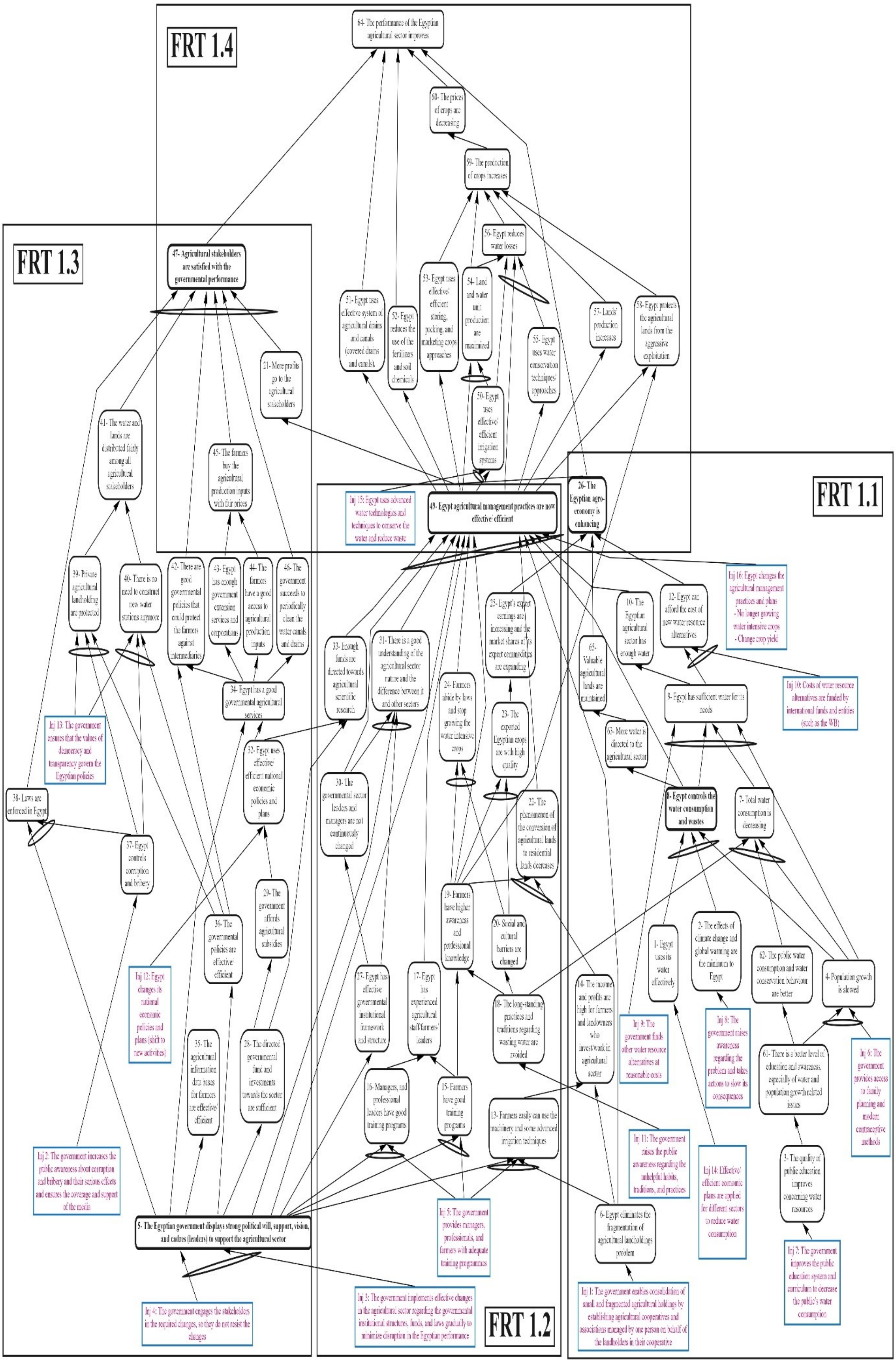

Figure 53: FRT1- Ensure the Egyptian agricultural sector's success.

It can be noted that the FRT improved the current reality and turned all the UDEs into DEs. It offered a comprehensive framework that acts like a prescription to eliminate a disease. This comprehensive framework was based on two main pillars. The first pillar was the injections/ solutions required to improve the ineffective/inefficient water and agricultural practices. The second pillar was the injections/solutions concerned with improving the Egyptian governmental performance.

The findings of FRT2

FRT2 tests whether the proposed solutions will improve the expected reality in light of the expected risks to Egypt's water supply due to the GERD in the near future. In this first of two scenarios including the GERD, a bilateral agreement to regulate the filling and operation process of the GERD at a slow pace is assumed to have been reached. This would maintain the status quo, with no reduction in the Egyptian share of the Nile water.

In this situation, only three main injections would be required, the key one being to keep the situation controlled as it is now. The main injection here is "Egypt has an agreement with Ethiopia to fill the GERD over a very long-term period, which will not affect the water's quantity or quality". This injection defuses the conflict, which would affect the rest of the expected UDEs and turn them into DEs. Table 31 shows the UDEs, injections, and DEs.

UDEs	Injection/proposed solution	DEs
2- Environmental degradation is on the increase.	Inj1: The government raises awareness regarding the problem and acts to slow its consequences.	2- Environmental degradation is controlled.
1- Ethiopia starts to fill the GERD reservoir by cutting the amount of the Nile's water annually.	Inj2: Egypt has an agreement with Ethiopia to fill the GERD over a very long timeframe, which will not affect the water's quantity or quality.	1- Ethiopia starts to fill the GERD's reservoir slowly by cutting amount of the Nile's water annually not exceeding 15%.
40- The population is increasing rapidly.	Inj3: The government provides access to family planning and modern contraceptive methods.	40- The population is growing slowly.

Table 31: The UDEs, injections and DEs of FRT2.

Figure 54 represents the complete FRT2. The complete diagram is segmented based on the subordinated FRTs as can be seen below.

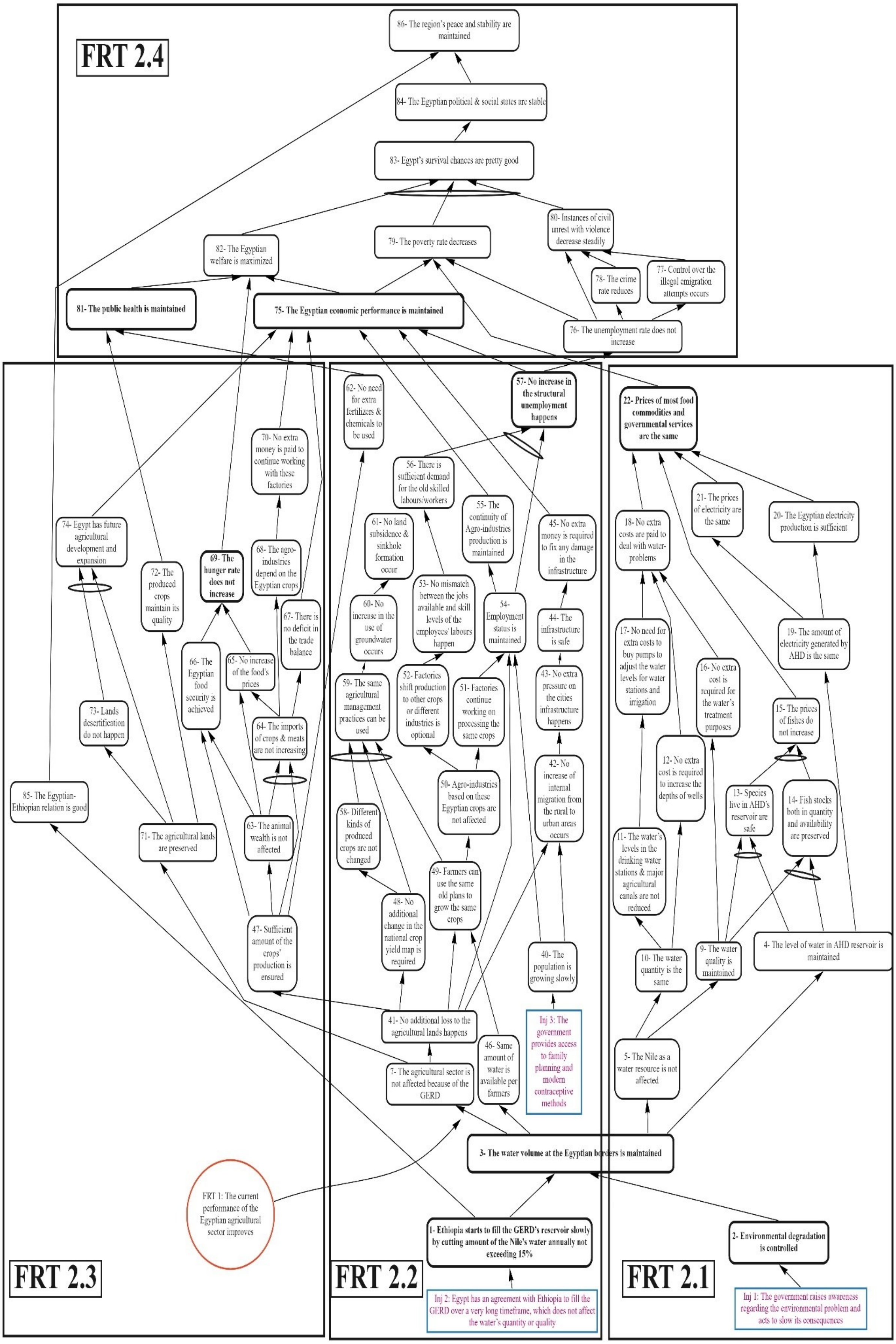

Figure 54: The FRT2- The situation due to the GERD, Scenario 1- Assuming a bilateral Egyptian-Ethiopian agreement.

The findings of FRT3

FRT3 presents the forecasted picture of "What to change to" in considering the expected risks to Egypt's water supply due to the GERD in a scenario where bilateral negotiations fail, forcing Egypt to make drastic cutbacks and changes, and find water resource alternatives. Table 32 shows the UDEs, injections, and DEs for this tree.

UDEs	Injection/proposed solution	DEs
2- Environmental degradation is on the increase.	Inj1: The government raises awareness regarding the problem and takes actions to slow its consequences.	2- Environmental degradation is held in check.
3- The volume of water at the Egyptian border decreases (the amount of the Nile's freshwater decreases).	Inj2: Egypt finds water resource alternatives.	3- Egypt maintains an adequate volume of water.
7- The water supply is insufficient to meet Egypt's needs.		6- The water supply is sufficient to meet Egypt's needs.
5- Using the Nile as the main water resource needs adjustment.	Inj3: Egypt utilises different water resources with the Nile.	5- Egypt does not rely on the Nile only.
14- Fish stocks decrease in both quantity and availability.	Inj4: Ethiopia pays for Egypt to take actions to mitigate the damage.	14- Egypt buys fish from other countries.
13- Species in the AHD reservoir are harmed.		13- Species in the AHD reservoir are moved elsewhere.
19- The efficiency of electricity generation from hydropower is not ensured.	Inj5: Egypt uses other renewable energy sources to generate electricity (solar plants).	19- The efficiency of the Egyptian electricity generation system is ensured.
20- The Egyptian electricity production is insufficient.	Inj6: Ethiopia sells Egypt cheap electricity.	20- The Egyptian electricity supply is maintained.
	Inj7: Egypt buys electricity from other countries.	
9- The water quality is affected.	Inj8: Ethiopia is responsible for water treatment.	9- The Nile's water quality is maintained.
16- The costs of the treatment of drinking water and irrigation increase.	Inj9: Ethiopia pays the required costs.	16- The costs of the treatment of the drinking water and irrigation are reasonable for Egypt.

UDEs	Injection/proposed solution	DEs
17- There is a need to buy pumps to adjust the water levels for water stations and irrigation.		17- Egypt does not experience extra costs to buy pumps to adjust the water levels for water stations and irrigation.
12- More costs must be paid to increase the depths of the current wells.		12- Extra costs that are required to increase well depths are covered.
7- The water supply is insufficient to meet Egypt's needs.	Inj10: Egypt reduces its national water consumption and waste.	6- The water supply is sufficient to meet Egypt's needs.
39- Huge costs must be paid to find and operate new water resource alternatives (desalination plants, drilling deeper wells).	Inj11: Ethiopia compensates/pays Egypt to fund new water resources. Inj12: Costs of water resource alternatives are funded by international funds and entities (WB).	39- Egypt can afford the cost of new water resource alternatives (desalination plants, drilling deeper wells).
40- The population growth is increasing rapidly.	Inj13: The government provides access to family planning and modern contraceptive methods.	40- The population is growing slowly.
8- Agricultural sector is seriously damaged because of the GERD.	Inj14: Egypt carries out precautionary measures of the agricultural management plans due to the GERD.	7- Agricultural sector is not impacted because of the GERD.
46- Less water is available for farmers.	Inj15: Egypt maximises the benefits of the water unit by using effective/ efficient water technologies and techniques to conserve water and reduce waste.	46- Same water is available for farmers.
47- Sufficient supply of crops for human consumption and agro-production is not ensured.	Inj16: Egypt imports the required crops from international markets.	47- Sufficient supply of crops for human consumption and agro-production is ensured.
52- Some factories working on processing these crops are forced to shift their production.	Inj17: Egypt provides the workers with the required training for the new jobs OR Egypt establishes new employment opportunities.	52- Factories can shift production effectively to use new crops.

UDEs	Injection/proposed solution	DEs
51- Some factories working on processing these crops are shut down.	Inj18: Egypt imports crops from international markets/ OR Egypt grows crops elsewhere by renting lands in other countries.	51- Factories continue working on processing the same crops.
76- The unemployment rate increases.	Inj19: Workers should be reallocated to other suitable positions OR Egypt opens new markets suitable for the workers' experiences.	55- The employment rate is maintained.

Table 32: The UDEs, injections and, UDs of FRT3.

Figure 55 represents the complete FRT3. The complete diagram is segmented based on the subordinated FRTs as can be seen below.

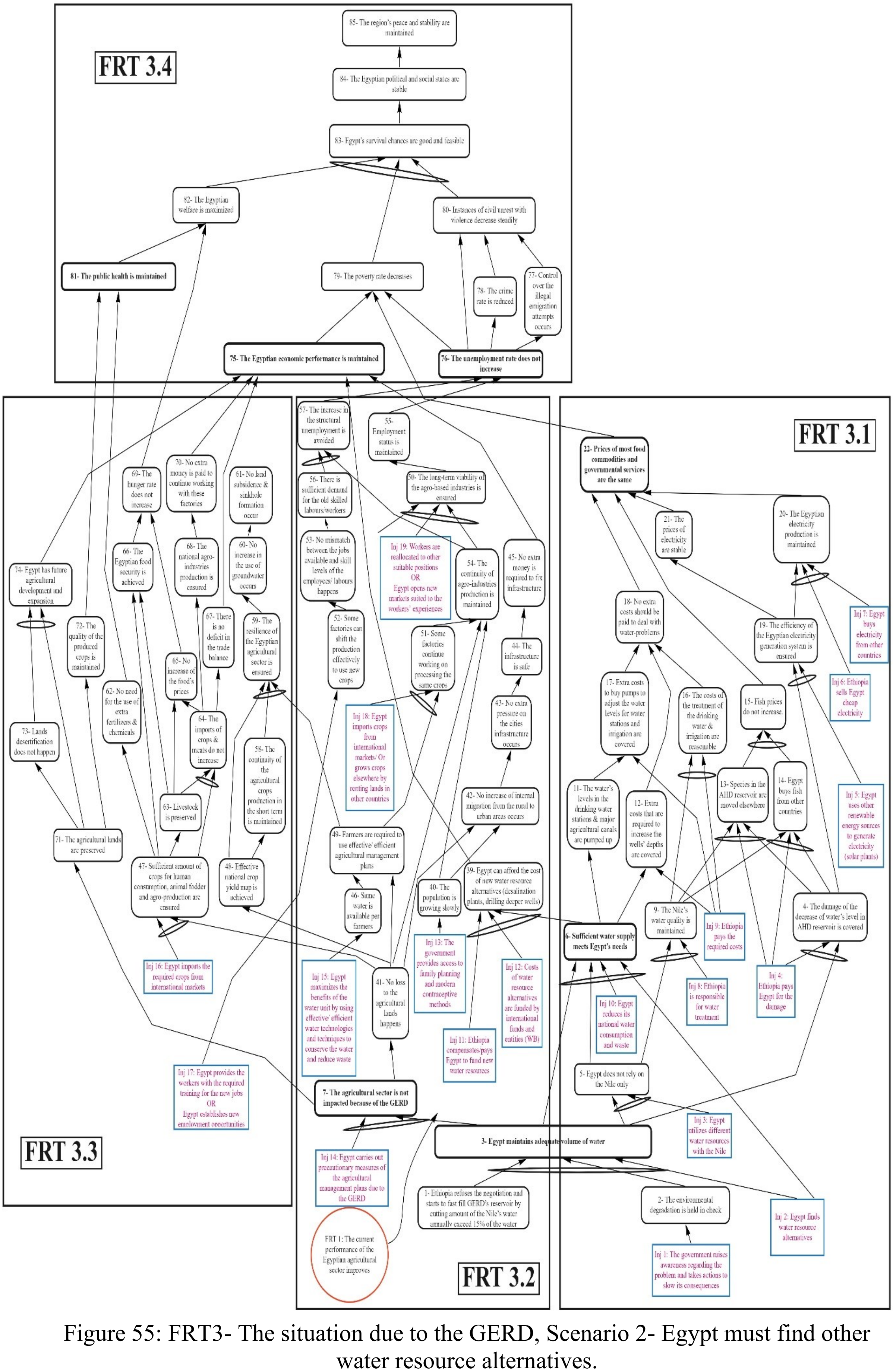

Figure 55: FRT3- The situation due to the GERD, Scenario 2- Egypt must find other water resource alternatives.

It could be stated that FRT3 offers a comprehensive solution to mitigate the expected risks to Egypt's water supply due to the GERD in the near future, while also finding other water resources. This comprehensive solution was based on three main pillars. The first pillar was the injections/solutions required to mitigate the impacts of the GERD on the water supply and agricultural sector. The second pillar was the injections/solutions needed to be achieved to mitigate the impacts of the GERD on electricity generation, agro-industries, and the increase in the unemployment rate. The third pillar was the injections or solutions, which are concerned with enhancing the government's general performance.

It is worth mentioning that some injections, such as Inj8: Ethiopia is responsible for water treatment, and Inj9: Ethiopia pays the required costs, are made based on the assumption that the international community will force Ethiopia to compensate Egypt, in response to the Ethiopian intransigence to move forward with the construction and operation of the GERD.

It can be noted that FRT1 acts as a subordinate tree for FRT2 and FRT3. FRT1 represents the solutions to improve the current issues of the Egyptian agricultural sector, which should in any case be a part of the bigger solution to mitigate the expected risks to Egypt's water supply due to the GERD, whichever assumption is chosen to underpin the situation.

It also can be seen that the environmental impacts because of the GERD, which the participants discussed in the CRTs, and their solutions, were not included in these two trees. This was due to the participants overlooking these impacts when they discussed the problems/conflicts in the ECs, and again when they suggested solutions for the FRTs. It can be concluded that the long-term threats from environmental impacts seemed less important to the participants, in comparison with the urgent and immediate threats they currently suffer.

7.2.5. Prerequisite Tree (PRT) analysis and findings

After answering the first three questions, PRTs are used to answer the fourth one "How to cause the change?". Mabin (1999) explains that the PRT is used to identify the obstacles (Obs) that block the achievement of a target and provide the actions (Intermediate objectives) needed to overcome these obstacles and the sequence in which they should be undertaken.

In this study, two PRTs are constructed to work on the obstacles blocking the implementation of the proposed solutions. The first tree works on the obstacles that currently block the proposed solutions to ensure the Egyptian agricultural sector meets the nation's needs now and, in the future. The second tree works on the obstacles that block the proposed solutions to ensure Egypt's survival if the construction and operation of the GERD go ahead as planned. The interviews revealed many ideas and strategies that positively overcome these obstacles.

Data for the PRTs was collected using interview question number 15 with two parts a and b (Appendix A). The question related to how to overcome the expected obstacles when implementing the proposed solution(s) is as shown below:

> 15) What obstacles do you think are likely to be faced when trying to implement the proposed solution?

a. In your opinion, how would you overcome these obstacles?
b. Have you developed (or do you know of) any strategies to overcome these obstacles?

Based on the answers of the participants, the obstacles were first identified. Then the ideas and strategies of how to overcome these obstacles were provided. These ideas were the basis for the IOs that identify the intermediate steps, which should be taken to overcome those obstacles. The existing and the future situations are considered 2 separate PRTs.

7.2.5.1. The first PRT1- The agricultural sector

The agricultural sector's PRT was mainly to overcome the obstacles that are blocking the target, "Ensure the Egyptian agricultural sector meets the nation's needs now and, in the future". This target is working closely with one of our goals related to how to improve the agricultural sector. The critical RCs for the problem were identified as: Egypt already suffers from water poverty, climate change and global warming, the population is growing rapidly, and the Egyptian government displays a lack of political will, support, vision, and cadres (leaders) to support the agricultural sector.

The TOC Thinking Processes (TPs) were applied step by step to find the solutions. The solutions (injections) to address these RCs were as follows:

- Inj9: The government finds other water resource alternatives at a reasonable cost.
- Inj14: Effective/efficient economic plans should be applied for different sectors to reduce water consumption.
- Inj8: The government raises awareness regarding climate change.
- Inj6: The government provides access to family planning and modern contraceptive methods.
- Inj3: The government gradually implements effective changes in the agricultural sector regarding the governmental institutional structures, funds, and laws to minimise disruption to Egyptian performance.
- Inj4: The government engages the stakeholders in the required changes, so they do not resist the changes.

<u>The first step</u> of the PRT is to determine the obstacles that block Egypt from achieving the stated objective. Dettmer (2007) argues that the obstacles within the PRT context may include a lack of resources, non-existent or insufficient required knowledge, lack of laws or regulations or limited laws that prevent certain activities and allow human resistance. The obstacles for the first PRT were articulated based on the answers of the participants.

The obstacles varied based on each individual objective and perspective and the category they belonged to (NL, LL, or IL). Some participants belonging to the NL discussed obstacles such as: the rapid increase of the population (Obs1), and the long-standing wrong practices and traditions (cultural, behaviours) that waste water (Obs3). Some participants belonging to the LL discussed the water not being sufficient to irrigate their lands (Obs22). Some participants belonging to the IL talked about ineffective Egyptian irrigation methods (Obs4), and the limited choices of crops that consume considerable water (Obs11). However, these obstacles were fully consistent with the RCs identified in the CRTs.

The second step is to provide ideas and strategies to overcome these obstacles. Where there are multiple suggestions to overcome an obstacle, Dettmer (2007) provides helpful criteria for the selection of the IOs in order to determine the most effective ones, as follows:

- The fastest, easiest, cheapest, most effective IOs to get the job done.
- The IOs produce less possible negative or collateral side effects.

The last step is to link the chosen IOs into a tree to reach the target at the top. This tree uses necessity logic.

In the first PRT, the proposed IOs were in line with Dettmer's criteria. These IOs were simple, practical, and cost-free (except for one IO); however, they needed high-level commitment, determination, and willingness to display strong political will, support, vision, and cadres (leaders) to support the agricultural sector by the Egyptian government. This could be seen through for example IO16a: the government employs effective and feasible agricultural laws and policies; or IO18: the government improves the effectiveness of the agricultural institutions. The expensive IO6a required finding new water resource alternatives. Nonetheless, it was the only effective IO that could truly help solve the problem of Egyptian water poverty. Table 33 shows the Obs and the respective IOs that could overcome them.

Objective (target): Ensure the Egyptian agricultural sector meets the nation's needs now and in the future	
Obstacles (Obs)	Intermediate Objectives (IO)
Obs1: The rapid population growth is a burden on the water and food supplies.	IO1: The government provides access to family planning and modern contraceptive methods.
Obs2: There is not enough money to explore these new resources.	IO2: Egypt finds international funds and loans to work on finding new water resource alternatives.
Obs3: Many long-standing practices and traditions (cultural, behavioural) are wasting water.	IO3: The government raises public awareness regarding unhelpful habits, traditions, and practices.
Obs4: Current irrigation methods are wasting water.	IO4: The government uses effective and advanced irrigation methods.
Obs5: Wasteful farming practices are used.	IO5: Farmers implement better farming practices.
Obs6: The Egyptian water supply does not meet the country's needs.	IO6a: Find new water resource alternatives with reasonable costs.
	IO6b: Egypt makes effective use of its water supply.

Objective (target): Ensure the Egyptian agricultural sector meets the nation's needs now and in the future	
Obstacles (Obs)	Intermediate Objectives (IO)
	IO6c/21: Egypt employs effective/efficient water national management plans and practices.
Obs7: Fragmentation of landholdings limits achievable production.	IO7: Egypt overcomes the fragmentation of agricultural landholdings problem.
Obs8: Egyptian government displays a lack of political will, support, vision, and cadres (leaders) to support the agricultural sector.	IO8: The government implements effective/efficient governmental institutional structure and laws.
Obs9: Agricultural scientific research is neglected.	IO9: The government funds more investments in the agricultural sector.
Obs10: Farmers suffer poor capabilities.	IO10a: The government provides professional agricultural services (extension services).
	IO10b: The government provides good education services.
	IO10c: The government provides infrastructure.
	IO10d: The government provides housing.
	IO10e: The government provides community services.
Obs11: The choices of crops are limited and consume a lot of water.	IO11: New strains of low-water intensive crops are developed.
Obs12: Egypt applies ineffective national crops yield map.	IO12: Egypt optimizes the national crops choices and yield map.
Obs13: The current crop management practices and plans are not effective/efficient.	IO13: Egypt improves the crop management plans.
Obs14: The Egyptian agricultural equipment and machinery are not effective/efficient.	IO14: Egypt uses updated lands technologies (equipment, machinery).
Obs15: The agricultural technologies used in Egypt are not effective/efficient.	IO15: Egypt uses updated advanced technologies (IT, sustainability, advanced thinking approaches, etc.).
Obs16: Egypt experiences widespread long-standing corruption and bribery.	IO16a: The government employs effective and feasible agricultural laws and policies.
	IO16b: The government increases public awareness about corruption and bribery and their serious effects and ensures the media's coverage.

Objective (target): Ensure the Egyptian agricultural sector meets the nation's needs now and in the future	
Obstacles (Obs)	Intermediate Objectives (IO)
Obs17: The agricultural institutions are not effective/efficient.	IO17: Egypt controls corruption and bribery.
Obs18: Egypt uses wrong agricultural policies.	IO18: The government improves the effectiveness of the agricultural institutions.
Obs19: The management of the Egyptian agricultural sector is ineffective.	IO19: The government improves the effectiveness of the agricultural policy framework.
Obs20: The agricultural management practices and plans are not effective/efficient.	IO20: Egypt employs effective/efficient agricultural national management plans and practices.
Obs21: The water management practices and plans are not effective/efficient.	IO6c/21: Egypt employs effective/efficient water national management plans and practices.
Obs22: There is not enough water for the agricultural sector.	IO22: Egypt has sufficient water amount to cover its needs.

Table 33: The Obs and IOs for PRT1 to ensure the Egyptian agricultural sector meets the nation's needs now and in the future.

The PRT can be read in two ways. The first is to read top-down starting from the overall target to the bottom as: In order to … <Upper IO>, we must … <Lower IO>, in order to get over <Obstacle>, or: In order to … <Upper IO>, we must … <Lower IO> because <Obstacle X>. The second way is to read bottom-up, by using: We need to … <Lower IO X> to get over <obstacle X> before we can … <Upper IO Y>, and so on up the tree until we can reach the <Target>.

The first PRT is shown in two parts in Figures 56 and 57, to aid readability. There are a number of IOs which are connected to IOs in the other part of the PRT, for which off-page connector symbols are used. These off-page connections are indicated using bolded IO numbers in a circle.

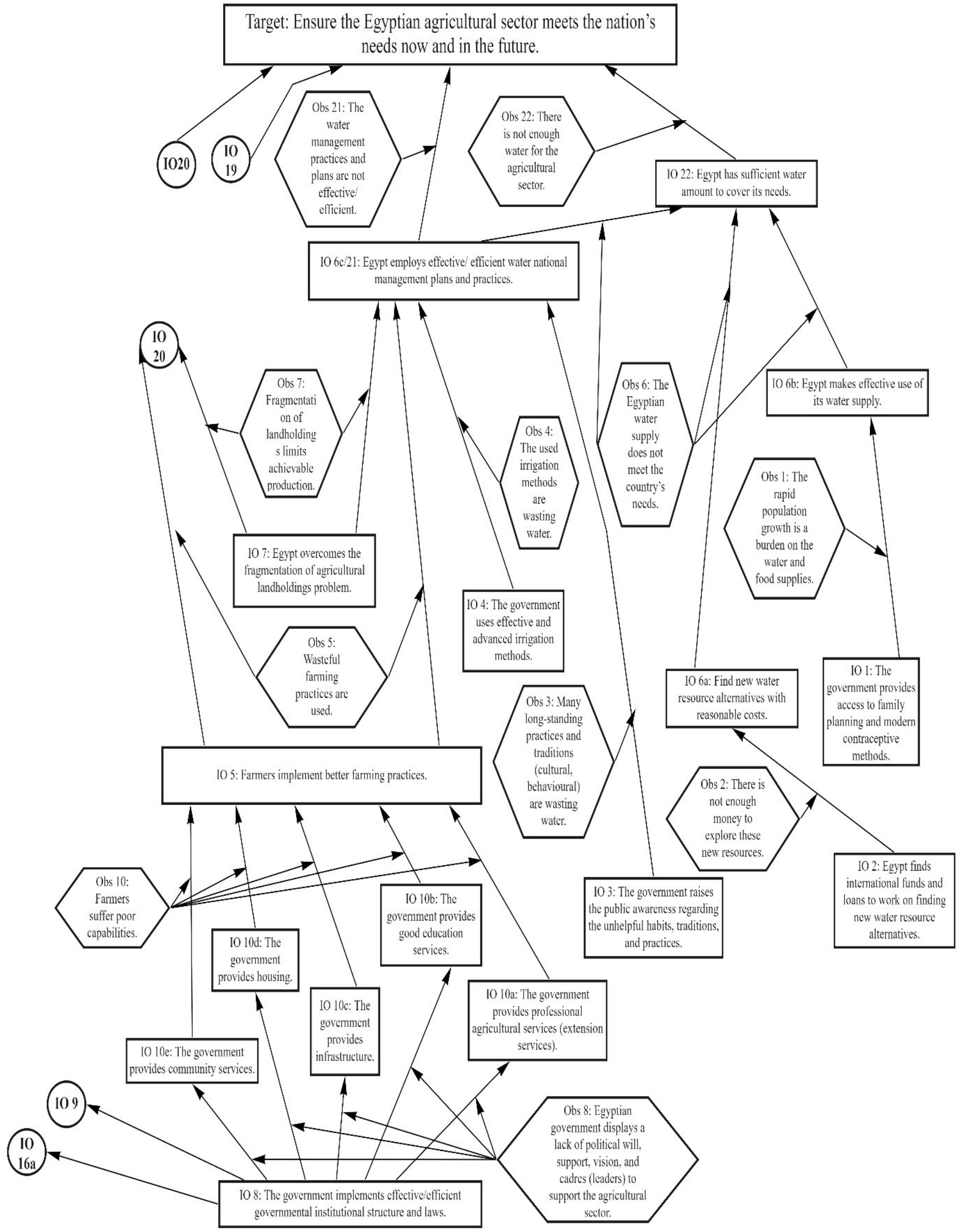

Figure 56: PRT 1.1- The agricultural sector.

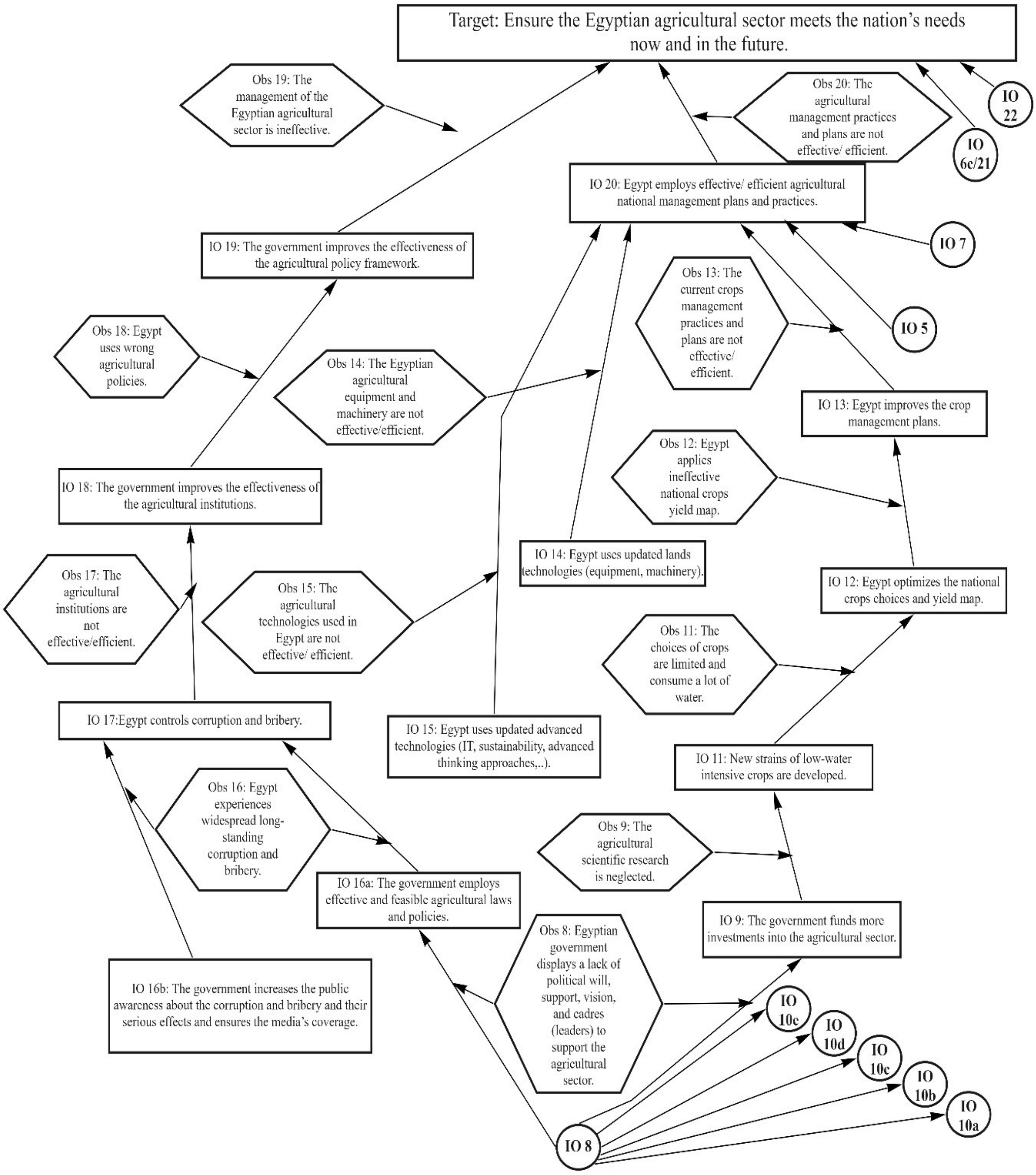

Figure 57: PRT 1.2- The agricultural sector.

7.2.5.2. The second PRT2- The GERD case study

The second PRT's main target was to ensure Egypt's survival if the construction and operation of the GERD goes ahead as planned. The Egyptian survival was the GTs' main goal. The critical RCs for the problem were Ethiopia starts to fill the GERD reservoir by cutting the amount of the Nile's water annually, environmental degradation is on the increase, and the water volume at the Egyptian border decreases.

Then the solutions to these RCs were many as was explained in the ECs and FRTs. However, finding other water resource alternatives came as a top priority. There is a pressing and crucial need for Egypt to confront the future by discovering these new water resources, as well as applying the other proposed solutions, as per the proposed PRT's objective.

*The researcher is well aware that it is not the typical situation of using the PRT. The obstacles addressed by a PRT are usually limited to **current** obstacles standing in the way of the target. However, under the exceptional circumstances of this case study, a little twist was done in constructing the second PRT by including the expected obstacles under the GERD scenario.*

The first step of the second PRT is to determine the obstacles that might block Egypt from achieving the stated objective. Some participants belonging to the NL category discussed the expected consequences of the GERD at the national level. They talked about the increase in the poverty rate (Obs20); the impact on Egyptian economic welfare (Obs19); the increase in the crime rate (Obs13); and the Egyptian water shortage because of the GERD increasing the water poverty rate (Obs1).

The participants belonging to the LL were more concerned with the agricultural problems facing farmers. They discussed the production of Egyptian crops being insufficient because of the water shortages (Obs5); agricultural lands are degraded (Obs4); and Egypt loses viable agricultural land (Obs8).

The participants belonging to the IL were more concerned with the industrial problems. They argued that there is insufficient money to construct the new energy plants required to overcome the shortage in hydropower electricity (Obs16); Egypt suffering a decrease in its GDP (Obs9); and that structural unemployment increases (Obs6). However, these obstacles were fully consistent with the RCs represented in the CRTs.

The second step is to provide ideas and strategies to overcome these obstacles, IOs. These ideas are already derived from the injections of the ECs. The last step is to link the chosen IOs into a tree to reach the target at the top. In the second PRT, the proposed IOs were in line with Dettmer's (2007) criteria for selecting effective IOs. These IOs were the fastest, easiest, the most effective IOs to get the job done, and produce the least possible collateral side effects; however, they were not cost-free because of the nature of the problem. Applying these IOs will need high commitment, determination, and willingness to display strong political will. This could be seen through some examples, such as: Egypt changes its economic policies and plans and shifts to new industries (IO2); Egypt imports crops from international markets (IO8); and (IO18) Egypt uses other renewable energy sources to generate electricity (solar plants). However, the required costs to fund these IOs were suggested through other IOs, such as: Ethiopia pays for constructing the new renewable energy plants (IO16), or the costs of new renewable energy plants are funded by international funds and entities (WB) (IO15). Table 34 shows the Obs and the IOs that could overcome them.

Objective (target): Ensure Egypt's survival in the case of the GERD	
Obstacles (Obs)	Intermediate Objectives (IO)
Obs1: Egypt experiences water shortages due to the GERD.	IO1/10: Urgently find new water resource alternatives.
Obs2: Workers are not qualified for the new jobs.	IO2a: Workers are re-allocated to other suitable positions.
	IO2b: Egypt establishes new employment opportunities.
	IO2c: Egypt provides workers with the required training for the new jobs.
Obs3: Egypt employs ineffective/inefficient economic policies and plans.	IO3: Egypt implements new economic policies, plans, and shifts to new industries.
Obs4: Agricultural lands are degraded.	IO4: Land desertification is avoided.
Obs5: Egyptian crop production is insufficient because of water shortages.	IO5a: Egypt imports crops from international markets.
	IO5b: Egypt grows crops elsewhere out of Egypt by renting lands in other countries.
	IO5c: Egypt changes economic policies and plans, and shifts to new industries.
Obs6: Structural unemployment increases.	IO6: Egypt achieves an effective agro-industry sector.
Obs7: The agricultural sector suffers huge losses.	IO7: Ensure the Egyptian agricultural sector meets the nation's needs now and, in the future (PRT 1).
Obs8: Egypt suffers a loss of viable agricultural land.	IO8: Egypt maintains agricultural land.
Obs9: Egypt suffers a decrease in its GDP.	IO9a/12a: Egypt achieves future agricultural development and expansion.
	IO9b/12b: Egypt maintains the viability of the agro-industry system.
Obs10: Human consumption and economic activities increase Egypt's water needs.	IO1/10: Urgently find new water resource alternatives.

Objective (target): Ensure Egypt's survival in the case of the GERD	
Obstacles (Obs)	Intermediate Objectives (IO)
Obs11: The decrease in agro-industry production happens because of the decrease in Egyptian crop production.	IO11: Egypt maintains the continuity of agro-industry production.
Obs12: The unemployment rate increases.	IO9a/12a: Egypt achieves future agricultural development and expansion.
	IO9b/12b: Egypt maintains the viability of the agro-industry system.
Obs13: Crime rate increase.	IO13: Egypt maintains the employment status.
Obs14: Egyptian electricity production is not enough.	IO14: Egypt ensures its electricity supply is sufficient.
Obs15: Egyptian energy management plans are ineffective/inefficient.	IO15: Egypt employs effective/efficient energy management plans.
Obs16: There is not enough money to construct the new energy plants.	IO16a: Ethiopia pays for constructing the new renewable energy plants.
	IO16b: Costs of new renewable energy plants are funded by international funds and entities (WB).
Obs17: Egypt receives an insufficient share of the hydropower generation.	IO17a: Egypt uses other renewable energy sources to generate electricity (solar plants).
	IO17b: Ethiopia sells Egypt cheap electricity.
	IO17c: Egypt buys electricity from other countries.
Obs18: Egypt suffers social instability.	IO18: Egypt controls the social/civil unrest.
Obs19: Egypt suffers poor welfare economics.	IO19: Egypt maximizes the Egyptian welfare.
Obs20: The poverty rate increases.	IO20: Egypt maintains its economic performance.

Table 34: The Obs and IOs for PRT2 to ensure Egypt's survival in the case of the GERD.

The second PRT was also divided into two subordinate PRTs for presentation purposes as shown in Figures 58 and 59.

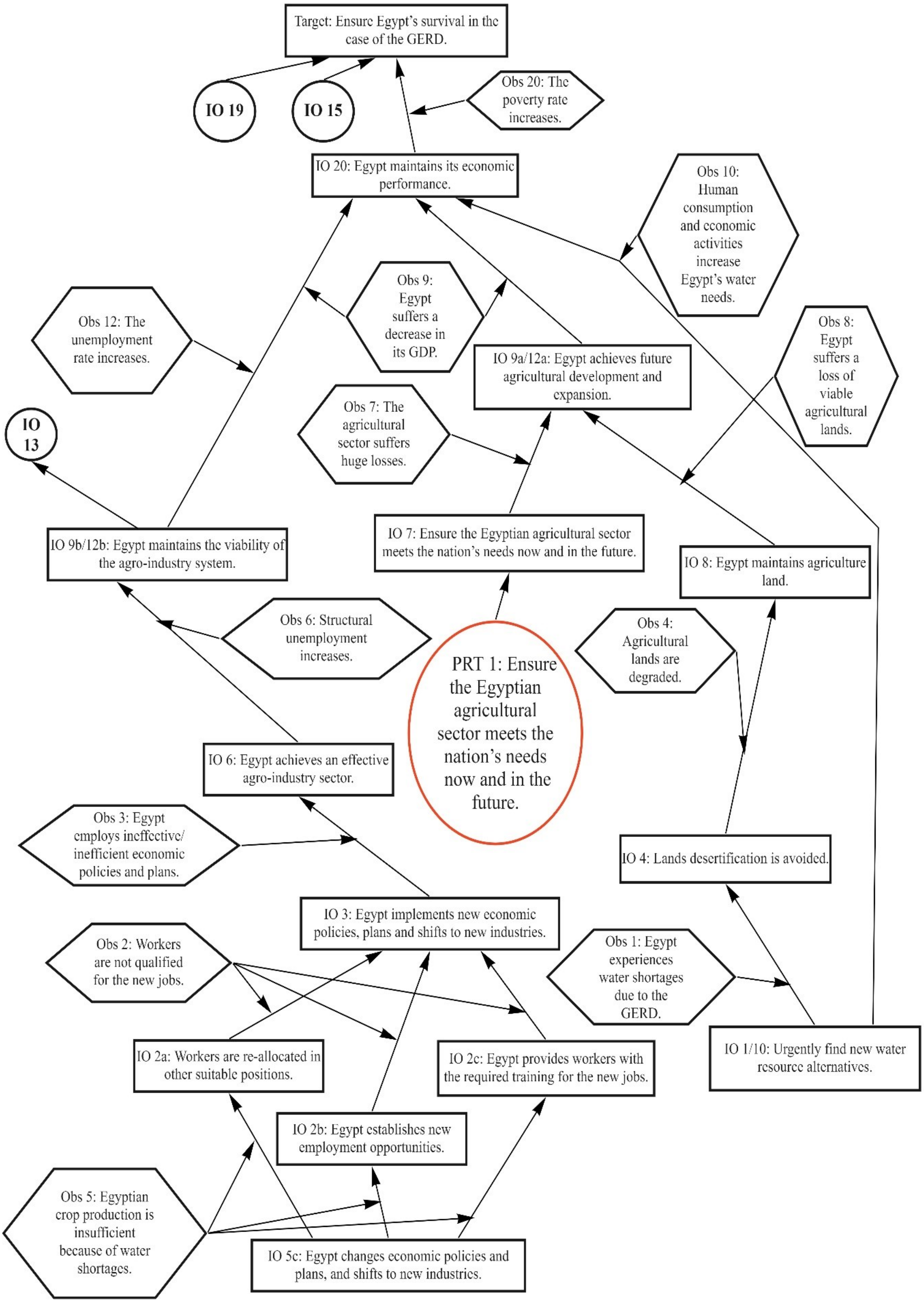

Figure 58: PRT 2.1- The GERD case study.

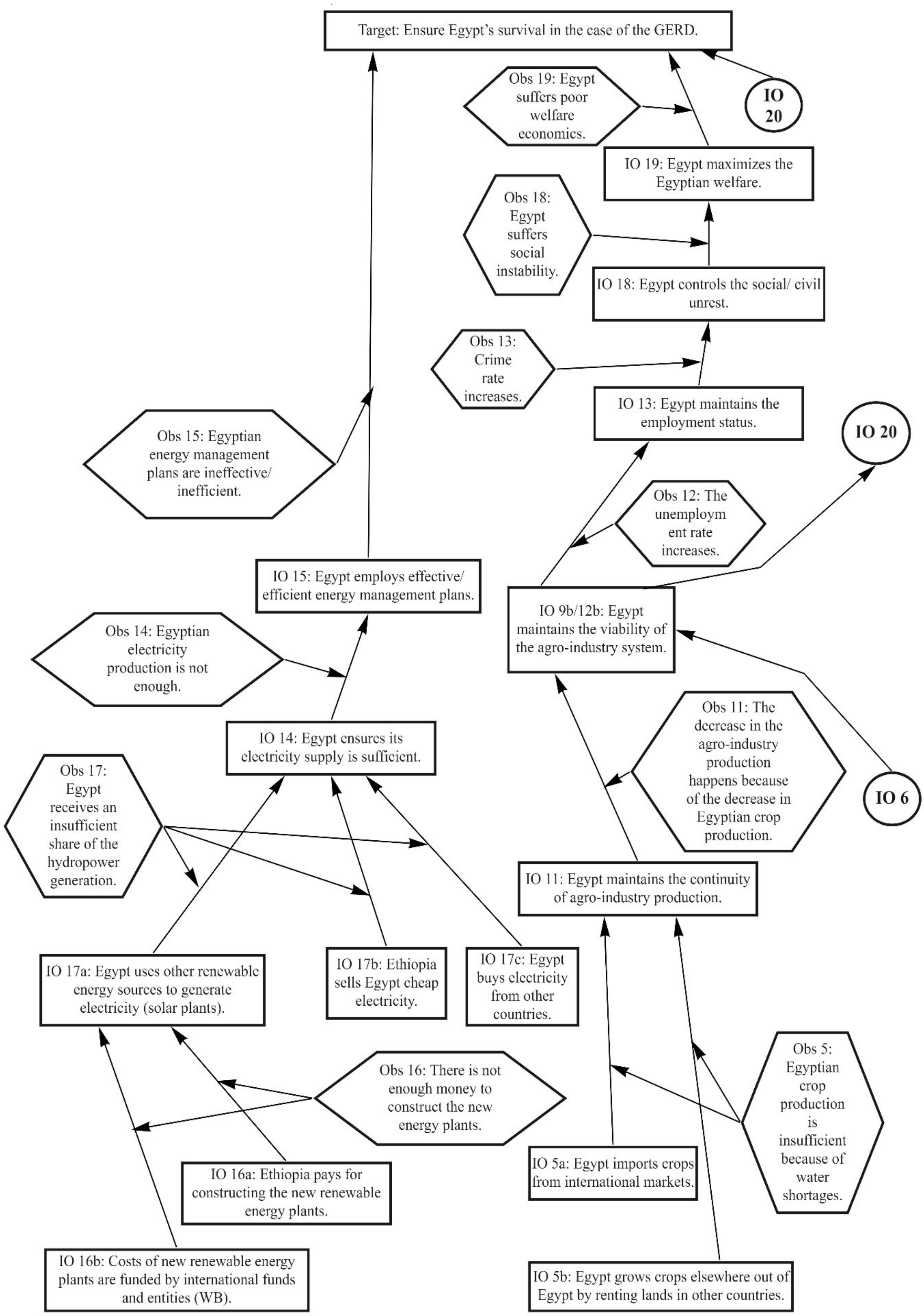

Figure 59: PRT 2.2- The GERD case study.

Commentary on participants' remarks

Few participants had general comments on this international dispute. Participant IL2 suggested that the European Union (EU) mediation could be useful; especially as they are the main importers of Egyptian crops. The participant added, "The European market shares common interests with the three countries, Egypt, Ethiopia, and Sudan, which makes the EU a partner that can fund the water projects to solve this dispute".

Participant IL4 claimed that the unstable political situation in Ethiopia is behind the Ethiopian intransigence over the GERD. He added, "The Ethiopian leader is trying to propagate his own false victory to unite different tribes and parties there".

Participant LL4/IL7 claimed that it is clear who could benefit more from the war in this unstable region. He added, "war would continue to benefit the arms traders. That could be shown clearly through the false news reports published on social media, which incite the populace and fuel the fires of the conflict."

The findings of the first agriculture-PRT

The first PRT clarifies the obstacles that could block the improvement of the Egyptian agricultural sector (the required target) and identifies the sequence of actions needed to overcome these obstacles.

The whole first PRT is represented in Figure 60, showing the two parts.

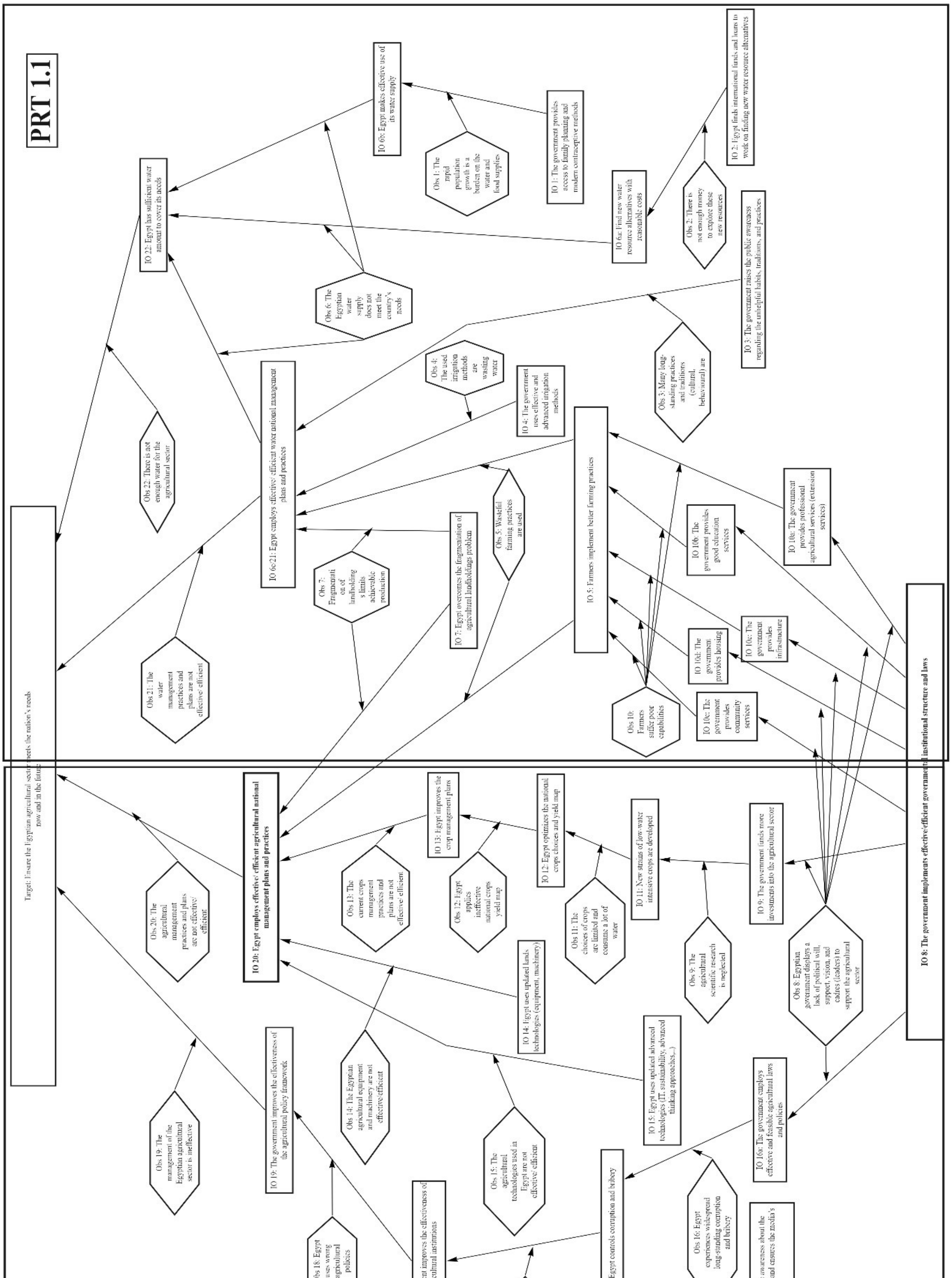

Figure 60: The first PRT- The agricultural sector.

It can be noted that the PRT succeeded in identifying the actions required for achieving our goal. It offered a comprehensive framework that acts as an action plan. This framework was based on two main pillars. The first pillar was the clear identification of the obstacles currently faced. The second pillar was the IOs concerned with overcoming these obstacles to ensure the Egyptian agricultural sector meets the nation's needs now and in the future.

The findings of the second GERD-PRT

The second PRT addresses the target of ensuring Egypt's survival if Ethiopia continues with its plans for filling and operation of the GERD without considering Egypt's needs. It surfaces the expected obstacles that would block the achievement of Egypt's survival in case of the GERD and identifies the sequence of actions needed to overcome these obstacles.

The second PRT is presented in Figure 61.

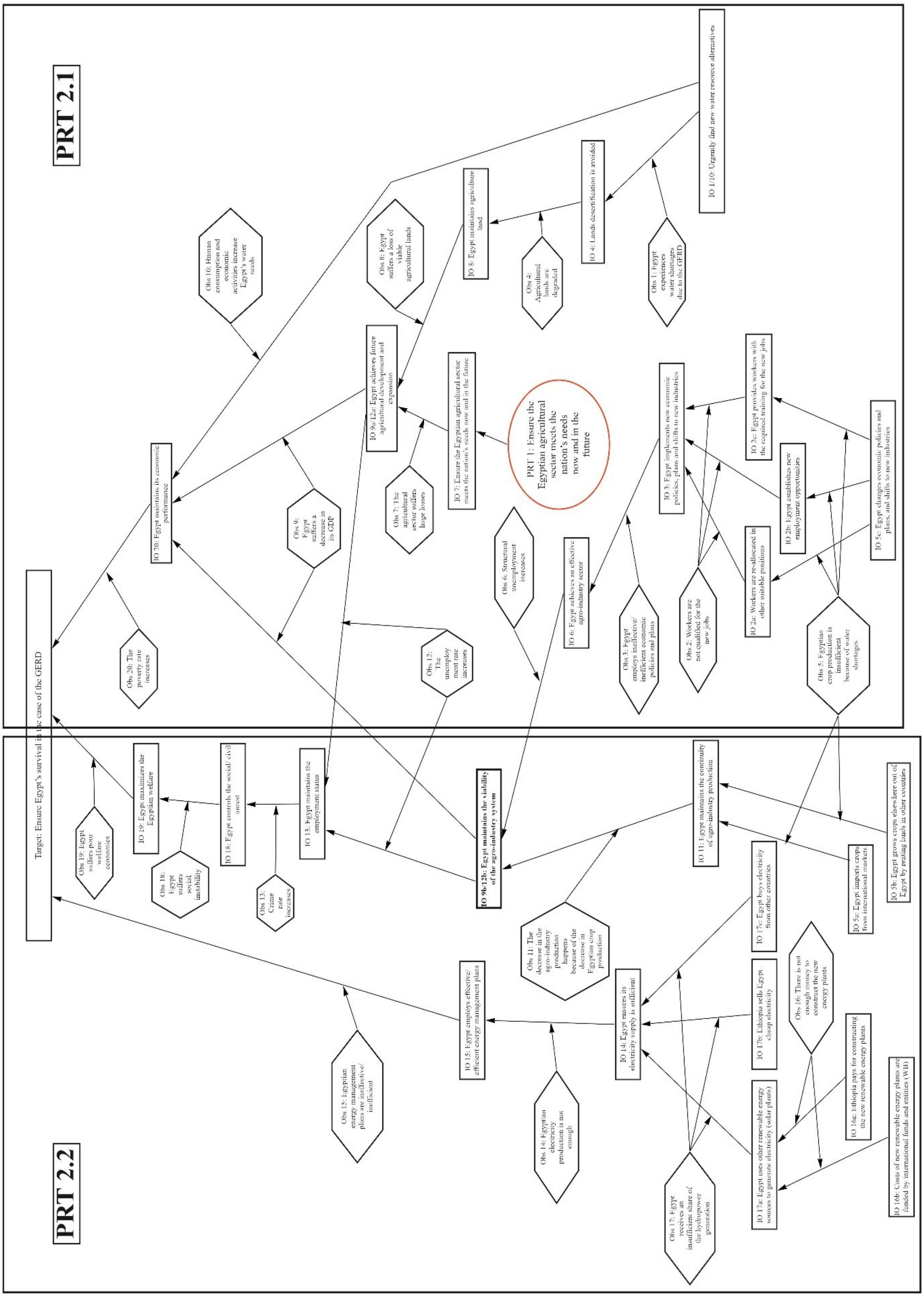

Figure 61: The second PRT- The GERD case study.

In PRTs, the actions at the bottom are the ones to complete first, before progressing to the next actions moving upwards. The obstacles and IOs at the top should not be of concern until the earlier (lower) ones have been achieved.

It can be noted that the PRT succeeded in identifying the actions required for achieving our goal. It offered an action plan that clarified the identification of the expected obstacles and the IOs necessary to overcome them.

The researcher suggests that Egypt should use the first PRT as an actual plan to ensure the Egyptian agricultural sector meets the nation's needs now and in the future. However, under the exceptional circumstances of the construction and operation of the GERD going ahead without considering Egypt's requests, the researcher suggests that Egypt should use the second PRT as a starting point to guide the implementation of new procedures now and in the future to overcome the expected obstacles. As events unfold, and new obstacles arise, the PRT can be adapted to incorporate additional IOs.

7.2.6. TOC 5FS analysis and findings

TOC 5FS provides a systematic framework to improve a system's performance by adopting a process of focused continuous improvement. The 5FS will be used first to identify the constraints that are limiting the achievement of the desired goals of the Egyptian agricultural sector in general and in consideration of the expected risks to Egypt's water supply due to the GERD in particular.
It will consider how the constraint can be exploited, what resources can be subordinated to assist the constraint, and finally elevate the constraint or mitigate its consequences. Finally, the whole process would be repeated in cases where the constraint has been broken, and/or new constraints emerge. This process is explained below.

Data for the 5FS was collected using interview questions 16-20 (Appendix A). The questions were asked to identify the most limiting constraint(s); how to use them effectively; other resources that could help to manage them; and how to obtain more of them as shown below.

16) Going back to the bigger picture, what is the biggest constraint you will face in your sector?
17) How can we use the existing (amount/level) of that resource (the constraint, eg. water) in the most effective way, more than they are used right now?
18) Are there any other resource(s) that could be used to help manage the constraint most effectively?
19) How can we get more of the constraint's resources (eg. water)?
20) Do you have any other comment you want to add?

- Step 1: IDENTIFY the system's constraint(s)

As explained in Chapter 3, every system must have at least one constraint that limits it from achieving its goals. Schragenheim (1999) divided the constraints into two main categories, physical and policy. However, both categories are usually related. Physical constraints are the limited resources that physically limit the system from achieving higher performance. Policy constraints cause the mismanagement of physical resources, which often turn these policies into constraints themselves.

Moreover, physical constraints can be internal or external constraints (inside the system or outside respectively). External constraints could include material constraints and market constraints. Internal constraints are easier to manage, while external ones are more difficult to control (Schragenheim, 1999).

In their interview responses, all participants identified the case study's constraint as currently having insufficient water supply, which is expected to be much less after the GERD construction is complete and operation begins. There was unanimity in considering the lack of water as the 'weakest link' that limits the improvement of the Egyptian agricultural sector in particular and threatens Egypt's survival in general. It was a definitive answer that no one thought twice about before stating. This is a physical constraint, material, outside of the system, which makes it extremely difficult to control.

As was mentioned before, Egypt's total annual amount of water is 67.5 bcm. The Nile contributes 82.2% of the Egyptian annual water resources (55.5 bcm), while 13.4% comes from recycled/reused water (9 bcm), 4% from groundwater (2.7 bcm), and 0.4% from rain (0.3 bcm) (Abdelsalam et al., 2014). The agricultural sector consumes 81.6% of Egypt's annual water resources (70% of the Egyptian share of the Nile's water), 13.5% for municipalities, and 1.57% for industry use (CAPMAS, 2017).

➢ Step 2: Decide how to EXPLOIT the system's constraint
The constraint's performance must be improved in order to improve the system's performance. First, an investigation is required regarding how the constraint is currently being used and where it is being wasted. Second, exploit the constraint, which means squeezing every bit of capability out of it before adding any additional resources (Dettmer, 1997) as any little gain on the constraint will result in overall system gain (Goldratt & Cox, 1984).

The investigation of how to make more effective use of the constraint (water) was done by collecting and analysing the answers of the 22 participants. The answers have been divided into four main categories to show how to exploit and squeeze every bit of capability out of the constraint from different viewpoints. Suggestions for improvement are closely related to the reasons for losses of the constraint (water) as follows:

1- Use effective and efficient irrigation systems

- Raise the efficiency of the current irrigation system. The current irrigation system efficiency is 50%, i.e., nearly half of the water used for agricultural purposes is wasted. This will save huge amounts of water and energy (participants NL2, NL4, LL3, LL7, IL2, IL3, and IL6). This could be achieved in several ways, all of which will require investment (addressed under Step 4 in detail):
    - Line the water canals to prevent water leakage (participants NL3/LL1, and NL8).
    - Change the irrigation of the canal and drain systems from open-water canals and drains to covered ones (participants IL4, NL6, LL8/IL11, and LL3.
    - Change the current irrigation system from flood irrigation to a sprinkler, drip or pivot irrigation system (participants NL6, NL8, IL2, IL3, IL4, IL5, IL9, IL10, LL2, LL3, LL4/IL7, LL5/IL8, LL6, and LL7.
    - Provide farmers with governmental financial support, and concessional bank loans (participant NL8).

- Use Supplemental Irrigation (SI). The SI can be defined as "The addition of small amounts of water to essentially rainfed crops during times when rainfall fails to provide sufficient moisture for normal plant growth, to improve and stabilise yields". It is when more than one resource of water is used to irrigate the same area. This helps in saving the Nile's water in some areas, using desalinated water or rain instead to provide some partial needs (participant NL4).

2- Manage the agricultural process effectively which includes:

- Choose the right crops to grow. More drought-tolerant crops must be grown, while water-intensive crops must be avoided. Moreover, grow drought-tolerant plants to decrease transpiration. Drought-tolerant plants have smaller leaves with fewer stomata, which reduce water losses from transpiration (participants NL1, LL5/IL8, LL6, IL6, and IL10).
- Develop new strains of crops that need less water (participants NL2, LL5/IL8, and IL3.
- Establish associations to organise better processes for using irrigated water among the farmers (participant NL3/LL1).
- Use modern mechanization (participant IL3).
- Reuse treated agricultural drainage water for irrigation (participant LL4/IL7).
- Use environmentally friendly sustainable agricultural practices to reduce water consumption (change types of fertilisers, use organic methods, etc.) (participant IL9).
- Use vertical farming methods which use 95% less water than traditional farming. It grows crops in vertically stacked layers, with controlled-environment and soil-fewer farming techniques. These avoid water losses due to evaporation and inefficient soil (participant NL5/IL1).
- Reduce post-harvest losses. Those losses result from poor management of post-harvest systems, which include "on-farm losses, such as when the grain is threshed, winnowed, dried, inadequate harvesting time, climatic conditions, practices applied at harvest and handling, and challenges in marketing produce". In Egypt, these losses are estimated at 15% to 50% for some crops. Reducing those losses by 50% will save 10% of the water used in the agricultural sector. Losses in crops are evaluated to exceed Egyptian agricultural imports (participant IL2).

3- Rationalise water consumption, which includes:

- Different campaigns to raise awareness. These campaigns should be made to reach all age groups (including farmers and normal citizens) and encourage water conservation as a national interest, directed especially against long-standing practices and traditions (cultural, behaviours) that waste water (participants NL2, NL4, LL3, IL9, and IL10).
- Use modern technologies to conserve water, such as sensors in drinking taps, water-saving showerheads, shorter showers, efficient clothes, and dishwashing (participants IL5, and LL3).
- Reuse treated waste water from baths, showers, and hand basins (participant LL4/IL7).
- Prioritise water usage based on its purposes (domestic, civic, public, industrial, agricultural, business, or trade) (participant IL10).

4- Manage the Nile's water

- Exploit the wasted Nile water into the Mediterranean Sea by storing or transporting the water (participant LL6). The average annual amount of the Nile's water flows to the Mediterranean Sea was estimated at 12.8 bcm (Yousif, 2011). Yousif (2011) draws attention to the possibility of using 5 bcm annually of this water that is currently wasted by flowing into the Mediterranean Sea while avoiding the expected environmental side effects on the Nile's Delta consequently. Yousif (2011) suggests transporting these 5 bcm via pipes, to avoid the loss of water by evaporation, to the Egyptian Western Desert to establish a new agricultural area.
- Green environments would help save the Nile's water. Planting trees is an efficient way to offset greenhouse gas emissions, which eventually improves the ecosystem.

➢ Step 3: SUBORDINATE everything else to the above decision

Since the constraint has been identified and exploited at the first two steps, it is now necessary to subordinate all the non-constraints to the decision made in step 2 in order to enhance the constraint's performance, which here is to effectively and efficiently use the water. In step 3, all the non-constraints must be managed in such a way that it suits the pace of the constraint to keep it running at full capacity, or in this case, to maintain the water usage and flow at maximum sustainable levels. This is needed so that the constraint is never idle due to a lack of supply from non-constraints (Goldratt & Cox, 1984).

However, in the case study, about 77% of the participants (17 participants out of a total of 22) saw that all other non-constraints really affect the shortage of water. The other 23% (5 participants) saw that there was another non-constraint that could enhance the constraint's performance slightly. This non-constraint is to use better equipment that could help in saving more water (participants NL1, NL3/LL1, IL2, LL4/IL7, and NL8). Nonetheless, these five participants said the equipment would have a limited effect on the current problem. The equipment includes bath taps, basins, showerheads, and irrigation equipment. In addition, crop strains that need less water could slightly reduce water needs.

Some points need to be considered to subordinate other resources that can be used differently to aid/serve the constraint, so water is used more productively, such as:

- Use water more efficiently.
- Cut back on consumption of crops.
- Change the crop yield.
- Control the long-standing practices and traditions (cultural, behaviours) that are wasting water.
- Change the public behaviour to use water more effectively/efficiently.
- Organise the water network's distribution and prices.
- Control population growth.
- Use effective/efficient agricultural practices and agricultural science.
- Maintain food/crop research.
- Change the irrigation methods used to reduce water loss.

Another way to subordinate other resources to the constraint is by applying the Drum-Buffer-Rope method. TOC believes that "a chain is no stronger than its weakest link". That means that any system is vulnerable because of its weakest link/bottleneck, which can always damage or break the system, or at least negatively affect the outcome. The bottleneck here is considered a drum, defining the overall speed of the whole system. The system cannot go faster than the drum. The key method to handle the constraint proposed in the TOC is the Drum-Buffer-Rope method (DBM), which generates logistical improvement by focusing on maintaining a buffer of work in front of the bottleneck, prior to the drum, to ensure that the constraint never runs out of work (Goldratt & Cox, 1984; Goldratt & Fox 1986), or in this case, never runs out of sufficient water

In this case, using some of the water stored in the AHD's reservoir could act as a buffer for some time to partially overcome water shortages. However, that could not cover the entirety of the expected water shortages. AHD's reservoir holds approximately 162 bcm, which is distributed as follows: 90 bcm of live storage capacity, 31 bcm of dead storage capacity, and 41 bcm the storage capacity for high flood water (Moussa, 2013).

According to the participants, dead storage is "the volume of water below the level of the spillway or other outlet, which cannot be released from a dam, unless the dam's wall bursts". Additionally, the storage for high flood water is based on the season itself. The only storage available to be used is the live storage, which cannot be completely used unless it is guaranteed that water will keep flowing as usual.

- ➢ Step 4: ELEVATE the system's constraint(s)
  In this case study, steps 2 and 3 alone are not sufficient to eliminate the constraint. At this point, however better the constraint's performance is, the amount of water available is still not enough to cover the required demands. Therefore, the constraint needs to be elevated. Step 4 is to elevate the constraint to another level by increasing its capacity. According to Dettmer (1997), there are different ways to increase this capacity through investing in time, energy, money, or other resources. Actions are needed to break the constraint, such as finding new water sources to expand the volume of water available and investing time and money to make better use of the available water. The researcher has ordered these actions to reflect the ones with the least expenditure required and greater ease of execution first.

First, invest to make better use of the available water:

- Develop new crop strains that can grow with less water (participants NL2, LL5/IL8, and IL3).
- Expand the use of greenhouse technology (participant IL6).
- As mentioned in step 2, invest in irrigation systems to raise their efficiency is one of the ways to increase the amount of water available to Egypt. This could be achieved in many ways, such as:
    - o Line the water canals to prevent water leakage and improve the field irrigation process. Lining canals can save 25% of the water loss through seepage (participants NL3/LL1, and NL8).
    - o Change the irrigation canal/drain systems from open-water canals and drains to covered ones to reduce the evaporation rates and pollution (participants IL4, NL6, LL8/IL11, and LL3.
    - o Most of the participants agreed that changing the current irrigation system from flood irrigation to sprinkler, drip or pivot irrigation systems would reduce at least 25% of the Egyptian water consumption

in agriculture. However, the expected establishment costs of the new systems would be expensive (participants NL6, NL8, IL2, IL3, IL4, IL5, IL9, IL10, LL2, LL3, LL4/IL7, LL5/IL8, LL6, and LL7.

- Provide farmers with governmental financial support, and concessional bank loans, to help/encourage them to change their irrigation systems (participant NL8).

Second, find new water sources:
There is a need to invest in finding new water resource alternatives to increase the constraint's capacity. The proposed alternatives, starting with the least costly, are rain and floods, groundwater, waste water and sewage recycling, seawater desalination, and establish and connect water networks to other countries as will be explained shortly.

1- Rain and floods

- Storing rain and floodwater could be useful in certain places, especially the Red Sea region (participant IL6). Participant NL1 suggested constructing non-rigid dams to collect the torrential downpour, adding "This water could be used in small-scale agriculture, or raising livestock."
- However, Egypt has generally extremely low annual precipitation rates, which usually do not exceed 1 bcm. Moreover, rainwater is not available everywhere in Egypt, only in certain places, and cities (participant IL2).

2- Groundwater

- Two participants IL2 and IL5 discussed the groundwater in the Nubian Sandstone Aquifer System (NSAS), which is considered to be the world's largest known fossil water aquifer system, as a good resource for water. This Aquifer is at the eastern end of the Sahara Desert and extends under four countries including north-western Sudan, north-eastern Chad, south-eastern Libya, and most of Egypt. The participants explained, "The water in this reservoir is limited, and Libya has been extensively using this resource by extracting substantial amounts of water for several years now". One of the participants discussed the Aquifer's location as a challenge. He said, "It is located in a desert area, which makes it hard to be reclaimed". The cost of transporting the water from the Aquifer to where it is needed would be extremely expensive as well as the cost of pumping the water to the surface. Pumps also require energy (electricity or fuel) to work.
- Participant NL2 commented on the NSAS as well. He warned that this resource should be used with caution. It is a non-renewable resource. Participant NL3/LL1 also argued that the use of groundwater, as a non-renewable resource, should not be excessive. It must be conserved for future generations.
- Participant NL2 illustrated that some wells have saline water. However, the levels of sodium and chloride are still less than in seawater. This makes well water less expensive to be treated.
- Participant NL5/IL1 commented that the Egyptian groundwater is limited to about 3 bcm, usually at depths estimated around 1,200 m which is expensive to pump up.
- Participant NL6 pointed out that there is groundwater in Wadi El-Hitan next to Farafra, New Valley Governorate that could be used.

3 - Wastewater and sewage recycling

- Participant NL8 explained, “There are three types of waste water, or sewage, which include: domestic sewage, industrial sewage, and agricultural runoff. Domestic sewage (also called sanitary sewage) carries used water from toilets in houses, public toilets, restaurants, cafes, schools, hotels, and hospitals. Industrial sewage is used water from industrial and manufacturing facilities or chemical processes. Agricultural runoff is water from farm fields due to irrigation, or rain, which contains pesticides, fertilisers, and sediment (soil particles)”.
- The possibilities for reusing each type of waste water are different, said participant LL5/IL8. Participant IL2 explained that pesticides, fertilisers, and sediment that contaminate agricultural runoff are sometimes hard to treat. He suggested that this water could be used in growing forests or woodlands, which do not produce crops to eat. Moreover, these forests do not need much water and will regulate the ecosystems, which will help in stopping climate change, increasing the rain and reducing the temperatures. At the same time, this is a safe way to get rid of agricultural runoff, as well as reduce the costs of treatment plants. The participant also suggested that some crops could be grown by using freshwater mixed with treated domestic sewage.
- Participant NL1 suggested renting some desert lands to the youth at cheap prices and using recycled waste water to grow non-food crops. These crops are used to produce goods for manufacturing, such as fibre for clothing, lavender, oilseeds like rape, linseed, and hemp for essential oils (while avoiding using any of these manufactured products in food), printing ink, and paper coatings.

4- Seawater desalination

- Participant IL2 explained that the cost of seawater desalination is estimated to be 16 Egyptian Pounds (EGP) per cubic metre of water without considering the operational cost of the plant. He added that the desalination of seawater could be used only for drinking purposes because of its high costs. He commented that the costs of drilling wells would be cheaper than seawater desalination.
- Participants NL6 and NL8 also agreed that seawater desalination is an extremely expensive alternative for water resources. Participant NL8 added that it should be used only for household and industrial purposes. Participant LL2 commented that it is not a practical solution for agricultural water demands because of its cost.
- Participant NL2 said, “This alternative is an energy-intensive process because of the energy required to separate salts and other dissolved solids from water, which makes it difficult to use right now”. He continued, “But might be more feasible after the construction of the new Egyptian Dabaa nuclear power plant that could supply sufficient energy for such activity”.

5- Establish and connect water networks from other countries

1. Congo river
   The Congo River was known as the Zaire River. It is the second longest river in Africa after the Nile. More importantly, it is the second-largest river in the world by discharge volume after the Amazon. This river flows from its sources in the Congo to the Atlantic Ocean, almost without being used. The Congo basin spans across nine countries, Angola, Burundi, Cameroon, Central African Republic, Democratic Republic of the Congo, Republic of the Congo, Rwanda, Tanzania, and Zambia. The Congo River carries about 1450 bcm of water annually, which

weighs 17 times the annual amount of water carried by the Nile. The flow of the river continues regularly during the whole year due to its extension to the north and south of the equator. This extension brings seasonal rains from both sides. The river is navigable in most places, with a few exceptions (Salman, 2013b).

The idea of linking the Nile-Congo rivers was first introduced by Sir William Edmund Garstin in his impressively detailed report about the Nile in 1904, "Report upon the basin of the upper Nile with proposals for the improvement of that river" (Garstin, 1904). To this day, this report is still a significant reference for the Nile basin.

Subsequently, several proposals have been made to connect both rivers. However, most experts agreed that the best one was executing a 600 km canal, which connects south Sudan to north Sudan and then to Lake Nasser (AHD reservoir), with an elevation of 200 m that needed 4 water stations to lift the water (Areq, 2020).

The researcher believes that the advantages of linking both rivers could be as follows:

- The huge discharge volume of the Congo River would maintain the Egyptian water security and solve the Egyptian water scarcity in the next coming years.
- This project would lead to producing vast amounts of hydropower, which would help the three countries (Egypt, Sudan, and Congo) achieve energy self-sufficiency. It would also turn Congo to be one of the biggest energy exporters worldwide.
- It will drastically improve conditions for the Egyptian agriculture sector and allow for agricultural expansion, which in turn, would increase the Egyptian food production and maintain food security.

However, some concerns must be taken into consideration to execute this project:

- The water direction of the Congo River is the opposite way of the Nile. The Congo River flows to the west away from the Nile. There is a need to establish a new canal to redirect part of this water to turn around to head to the northeast to meet the Nile (Areq, 2020). The researcher believes that more studies are required to find the best way to redirect the water.
- This project would be passing through many countries, some of which suffer from political turmoil and social unrest. This could make it difficult to guard and protect the constructions and the workers (Areq, 2020). The researcher believes that establishing new communities in these places, and redirecting Egyptian investments to pave the way for significant long-term gains could be extremely useful. This would create new urban communities, which in themselves could protect the project, especially if the workers are locals.
- It was estimated that this project could increase the Nile discharge by 100 to 120 bcm/year. This is more than the double amount of water Egypt receives annually (Areq, 2020). The size of the river pathways in Sudan cannot carry all this water. The researcher sees that as the biggest

problem. There are two different ways to handle it. First is the expansion of the river pathways in Sudan by increasing its width or its depth. This will need some time to plan and execute. Second is constructing some dams in Sudan to store water, which Egypt could temporarily use until the completion of the expansion work, by renting some Sudanese lands to grow crops.

Overall, this could be a very promising project. However, many studies are still required so it could be fully adopted and implemented in the future.

2. The completion of the Jonglei Canal Project (JCP)
The White Nile, the other main tributary of the Nile, flows from Lake Victoria in East Africa and receives water at the confluence of the Sobat and Bahr al Ghazal at El-Sudd. El-Sudd is a vast swamp in Baḥr al-Jabal region, South Sudan. The water in this region is the most water lost from the White Nile, evaluated by 14 bcm/year, due to transpiration and evaporation at the swamplands and their slow currents. This region is estimated by 5 to 8 thousand km^2 (De Mabior, 1981).

The Jonglei Canal Project (JCP) aims to divert the White Nile water through a canal to bypass the swampland to the East of El-Sudd to reduce water loss by transpiration and evaporation at the marshes and wetlands. The canal should divert the water from Baḥr al-Jabal swamps and link up with the junction of the Sobat and White Nile at Al-Ganal, a small town south of Malakal (De Mabior, 1981). According to the 1959 Agreement, this additional water should be split evenly between Egypt and Sudan upon completion (Doran, 2009).

The soil type surrounding the area of JCP is characterized as a clay, alluvial/lacustrine variety, which comes from the remaining sediments from the Nile. This is an extremely high-fertile area. However, it also has poor drainage qualities and is difficult to work manually (De Mabior, 1981). These poor qualities lead to waterlogged soil (the soil saturated or full of water), which in turn, leads to mineral dissolution causing soil contamination. This could also affect the growth of low water-intensive crops due to the drowning of their roots (Doran, 2009). However, these agricultural challenges could be overcome by executing surface drainage systems or by deep soil ripping and ploughing (De Mabior, 1981). What makes it worse is the rainy season, between May and September, which causes flooding in the region that effectively stunts agriculture and trade during this season (Doran, 2009).

The JCP was first introduced in 1901. However, the official plans for execution were made and announced in April 1974. According to the plans, the canal length is 360 km, the width varies between 28 to 50 m, the slope varies from 7.0 to 12.5 cm/km, and the depth is from 4 to 7 m. Plans included four crossing points and motorized ferries. The canal is also navigable by rivercraft. This canal reduces the route from Juba to Malakal by 300 km (Howell, 1983). The construction started in 1980 and had to stop in 1983 due to the outbreak of the Sudanese civil war (Doran, 2009).

This project has some positive aspects related to economic development and industry, while some other concerns were related to culture and environment. On one hand, the positive aspects are as follows:

- It will improve mobility and commerce in the region by allowing navigation through the canal in all seasons, especially in the rainy seasons when using other means of transportation are more difficult.
- It will promote development opportunities in the region with cheaper and more plentiful import and export of goods to Upper Nile and Jonglei State.
- It will provide the region with cheaper import and export of food, especially in the rainy season, when food is very limited and prohibitively expensive, which will maintain food security.
- Studies showed that there is a huge water loss in El-Sudd area, estimated by 50% of the Nile total flow passing by. Thus, this canal "will relieve many areas downstream which over the last 20 years have been subjected to severe flooding, and at the same time 'increase the potential for riverain grazing to be uncovered during the dry season" (Howell, 1983).
- The benefits to agriculture should not be overlooked. The region now suffers from limited water availability. The continuous availability of fresh water will allow large-scale agricultural projects, which when would combine with agricultural mechanization and fertile soil will result in producing a large amount of crops (De Mabior, 1981).

On the other hand, the concerns were as follows:

- This canal will change the traditional lifestyle and landscape of the whole area. The Sudanese government in the 1970s appropriated large swaths of territory, from Sudanese tribes, that was required for canal execution. The government still owns the lands; however, to date, these tribes were not financially compensated, which has fuelled a growing outcry over the years until now. Such a situation only serves to further tensions, mistrust, and bad publicity for the project (Johnson, 2006).
- Many parties involved in this project were engaged in presenting misinformation for different political aims. There were two versions of the plans of the JCP. The first one was for the canal's capacity of 55 million cubic meters (mcm)/day with severe environmental and social impacts, while the second was 25 mcm/day with mitigated environmental impacts (Howell, 1983). These details are still unclear to the Sudanese. Other claims were based on that two million Egyptian farmers would be resettled in the canal area to farm the potential farms as well as the common belief that Egypt would not deliver on its promises to the South (De Mabior, 1981).
- The execution of the canal would cause the draining of the El-Sudd to a certain degree, which would lead to permanently or seasonally drying out inundated lands. Some other negative environmental impacts include changes in the availability of fish, and a change in the grazing habits of cattle (Howell, 1983).

The researcher believes that the completion of this project should be urgently explored. Such exploration may do well to consider the following points:

- First, the Sudanese tribes, who owned the appropriated lands, should be financially compensated by the Egyptian and Sudanese governments.
- Second, the Egyptian government should establish media and information campaigns in South Sudan to clear the air and publish clear information about the project as well as to engage the Sudanese people in the decision-making process, to address resistance to change.
- Third, the Egyptian government should establish an Egyptian culture centre, service centres, and hospitals in the area.
- Fourth, advantages should be taken of the new arable lands created by drying out some inundated lands enabling new agricultural possibilities. Any remaining negative impacts have been shown in the most recent studies with the revised project to be capable of mitigation.

3. Some other suggested projects
    - Ethiopia has generous water resources. It will be helpful if the two countries can reach a bilateral agreement under which Ethiopia can sell some water to Egypt at reasonable prices. However, the cost of establishing the water network pipelines between the two countries would be expensive.
    - Lake Victoria-Mediterranean Sea navigation line linking project is another important project. This project would connect the north to the south of the African continent. It starts from Lake Victoria, passes by the rest of the tropical lakes in Uganda, reaches the borders of Sudan, then El-Sudd, White Nile and continues to meet the Subat River then the Blue Nile, the Atbara River, Wadi Halfa, the Marwa dam in Sudan, and then it reaches Lake Nasser to Aswan until it extends to the Mediterranean Sea, Alexandria Port through Rasheed Branch or Damietta Port via Damietta branch. This project could help Nile basin countries to use river transportation instead of roads, which would save fuel, reduce the cost of road maintenance, and reduce traffic jams and environmental pollution. However, this would require refinement procedures along the course of the Nile (State Information Service, 2017). The researcher believes that this project could strengthen ties between Egypt and the rest of the Nile basin countries, which could influence regional developments. This will be an opportunity for further progress in enhanced cooperation in the whole region.

Commentary on participants' remarks

There were some general comments on water resource alternatives by some participants:

- Participant NL8 discussed the idea of virtual water. He said, "While discussing the costs of water resource alternatives, we should also consider the costs of importing products with the highest virtual water content. That could save a lot of water".

- Many participants agreed that for water resources under Egypt's control, except for seawater desalination, the rest of the water resource alternatives (groundwater, waste water and sewage recycling, and rain and flood water) are insufficient and inadequate to provide Egypt with water, because of their very limited amounts.

However, seawater desalination is considered one of the most expensive alternatives (participants IL6, LL4/IL7, and NL5/IL1).
- Participant NL1 said, "The Congo-Nile connection is very important for the region's water security. New cooperation among the Nile basin States is also required to construct a huge dam on the Congo River to generate electricity, which all of them could use with minimum costs, or for storing water,"

- Step 5: WARNING! If in the previous steps, a constraint has been broken, go back to step 1, but do not allow INERTIA to cause a system's constraint.
  The 5FS is a process of ongoing improvement because new constraints will appear after breaking the old one. If there is any new constraint, it is necessary to go back to step 1 and repeat the process and be aware of inertia. It is important not to relax after the first constraint is broken because this cycle never ends. Moreover, it is necessary to review the process frequently (Goldratt, 1990).

In this case study, the researcher predicts that if the previous four steps are efficiently applied, it would be possible to get to step 5. Moreover, the researcher noted that a highly significant constraint could be represented in the latest Ethiopian and Sudanese proposals for building more dams along the Nile.

The findings of the 5FS
Based on the previous analysis the solution was constructed using steps 2, 3 and 4 of the 5 FS. The researcher recommends applying all these steps to mitigate the severe scarcity of Egyptian water, which is expected to worsen with population growth, climate change, and global warming.

Step 2 entailed the exploitation of the constraint where suggestions for reducing the amount of lost water were organised into four categories:
- Use more effective and efficient irrigation systems: lining the canals and changing the current irrigation system from flood irrigation to sprinkler, drip or pivot irrigation systems alone could save 50% of water losses.
- Manage the agricultural process more effectively.
- Rationalise water consumption.
- Manage the Nile's water.

Step 3 was where everything else should be subordinated to the constraint. In order to subordinate everything else a focus on using better and more effective equipment was recommended. A good choice of crop strains that need less water could be slightly helpful in reducing water needs as well. Moreover, the DBM offered a partial solution based on a buffer using some water from the AHD.

Step 4 was the elevation of the constraint where capacity is added if it is needed. For our case, it will be necessary to add capacity to our constraint. Steps 2 and 3 are not sufficient to eliminate the constraint. Even though they would improve the constraint's performance, it is still not enough to cover the water demands. Hence the need to make more recommendations, the most important of which is finding new alternative water sources. These resources could include rain and floods, groundwater, waste water and sewage recycling, seawater desalination, and establish/connect to water networks in other countries.

The recommendations provide an opportunity for Egypt to potentially save more water now and find more resources for the future. The researcher recommends applying all the suggested strategies in steps 2 and 3 to save as much water as possible. There was one reservation expressed in relation to the recommendations, which was more related to the costs of the new water resources. In this context, the researcher recommends classifying the new water resources based on their costs. However, this should be a national plan organised by the government. Egypt needs to decide if it will continue with the current water policies or make a change to improve the performance of the system based on these recommendations.

The researcher noted that the 5FS helps us to do everything in our power to make the most of every drop of water we have. This research is totally focused on the agricultural sector. However, the other Egyptian industries and sectors should follow suit to make the best use of the water constraint nationwide for Egypt's survival, which is the main goal of this study.

7.3. Summary

This chapter has used the TOC to diagnose and suggest solutions for the problems discussed in this study. Five tools of TOC TPs tools and TOC 5FS have been brought together to cover all aspects related to the current situation. The chapter has also provided the analyses and findings of each tool.

Chapter 8
Discussion of Findings

8.1. Introduction

This chapter synthesises findings presented and analysed in earlier chapters. It starts by restating the aims of this study. It is then followed by a detailed discussion that integrates the various perspectives and framing approaches to show how the application of these approaches helped in the understanding of the problem(s). The chapter ends by highlighting the value of the multi-framing analytical approach.

8.2. Aims/research questions and objectives

This research sets out to study the risks to Egypt's water supply due to the GERD. The aim was to understand the nature of the studied risks to Egypt; identify the RCs; evaluate expected risks; understand how to control, alleviate, and mitigate them; and then address the implications for Egypt, focusing particularly on Egypt's agricultural sector.

Previous studies of the Egyptian-Ethiopian conflict had focused on very limited aspects, using one-dimensional analyses. These studies do not consider the many other aspects and impacts that could affect the situation and outcomes. The nature of the situation itself is so critical and complex, using a one-dimensional view prevents an adequate understanding of the situation and its RCs, and limits the options open to consideration.

The study was intended to address this research gap to achieve the research objectives, via the following research question: "What are the expected risks to Egypt's water supply due to the construction and operation of the GERD in general and the consequent disruption to Egypt's water supply and impacts on the agricultural sector in particular, and how can Egypt deal with these risks?"

To ensure a sufficiently broad study, other sub-questions were posed and addressed by a series of frames, namely:

1) What is the nature of this situation (from each of the chosen perspectives)?
2) What are the relationships, challenges, and risks for the agricultural sector related to water supply shortages in Egypt due to the GERD construction and operation?
3) What are the root causes of the conflict (between Egypt and Ethiopia)?
4) What are the root causes of the agricultural sector problems before the expected impacts due to the GERD?
5) How can the consequences of this situation be identified, controlled, alleviated, and evaluated?
6) How a better understanding of the uncertain nature of the current situation could be gained to provide different stakeholders and decision makers with deep insights that can support their decision-making process?
7) What are the current and expected implications for Egypt due to this situation?
8) What are the suggestions for possible alternatives that when implemented could help to overcome these risks and lead to practical solutions for decision makers and stakeholders?

8.3. The road to meeting the objectives of the study

The main objectives of this study were achieved using multi-dimensional analyses adopting multiple perspectives within a multi-framing approach. Different frames were chosen for this multi-frame approach.

Relevant insights were generated through the contextual literature and different stakeholders' perspectives of the problems relating to the agricultural sector in Egypt provided during interviews. International experts' views provided insights relating to the international situation of the dispute. These insights enriched the researcher's perceptions of the risks, relationships between such risks, their causes, effects, and possible solutions to this conflict from different points of view, and ultimately to inform the best decisions to make for Egypt. In addition, these insights helped in gaining a better understanding of the situation and provided a base for the analysis of the multi-framing analytical approach.

That is why it is important to briefly shed light on the problem from the existing literature before entering a discussion of the findings. The ensuing discussion will show the evolution of the researcher's understanding of the situation and problem(s) relating to the risks to Egypt's water supply through the use of a multi-framing analytical approach.

8.4. The 'problem' from the context of the literature

The contextual literature contains many views about the risks to Egypt's water supply arising from the GERD. The challenges regarding the Egyptian-Ethiopian situation have led researchers to several important discussions, built through one-dimensional analyses, using one perspective, or a maximum of two, at a time.

For instance, some of these studies adopted a historical perspective (Carroll, 1999; Okoth-Owiro, 2004; Ferede & Abebe, 2014). These studies explored the treaties and agreements between the two countries. Interpretations of history represented in these treaties played a significant role in this dispute. It is extremely important to fully understand the past, to better evaluate options for the present. These studies explained the two countries' points of view regarding the treaties well. However, their weakness lay in adopting a one-dimensional historical perspective to assess the situation. It is not enough to simply work on the past without taking into consideration the other factors that could offer different perspectives.

Another perspective that scholars have used to study the conflict is the legal perspective (Salman, 2007; Abebe, 2014). There are many rules relating to the security and uses of transboundary water bodies. The most important three rules are HRs (1966), UNC (1997), and BRs (2004). The strengths of these studies stem from shedding light on the legal view of the conflict. However, the weakness is that the legal perspective is insufficient to reveal the problem's ambiguity. The problem is too complicated to be studied from one perspective.

One of the approaches to studying risks was using simulation techniques. Simulation is used to show the expected decrease of the Egyptian water share because of the GERD (Sadek, 2012); the impacts on the irrigation pumping stations along the Nile in Egypt (Ismail, 2013); the impact of the reduced water on Egypt's socio-economic projects and expected damage in drinking pump stations (Sadek, 2013); the expected reduction in hydropower generation from the AHD, if the GERD's reservoir were to be filled in less than six years (Mulat & Moges, 2014); along with other negative risks to Egypt if the reservoir filling time does not exceed six years (Ramadan et al., 2015).

Simulations, however, rely on the set of assumptions underpinning them, so they model scenarios that may or may not eventuate. The studies analysed specific situations to provide basic background estimates for this research. However, they were not sufficient to gain a better understanding of the whole situation; for example, they did not question the RCs of the situation or explore different ways of managing the situation other than exploring different scenarios. These studies were by their nature very focused on the quantitative aspects, which prevented them from capturing the complexity of the overall situation.

Some other analytical tools and approaches were completely missing from the literature. TOC frames, decision-making frames, and PIM appear to have not been used before to study this dispute. Such methods would help capture the big picture of this complicated situation.

8.5. The 'problem(s)' as implied from viewpoints from the field study

In this study, enhanced insights were gained by providing the opportunity to different stakeholders and experts at both international and national levels to express their views and opinions related to the case study during interviews. These interviews were used to collect data for the PIM, decision-making, and TOC frames. These insights helped to improve the researcher's understanding of the issues/problems covered in the literature, while also revealing unexpected new issues/problems.

These problems could be framed to reveal two different situations that give rise to ineffective managerial practices within the case study. The first case is the current situation of the agricultural sector, while the second is the situation in light of the expected risks to Egypt's water supply due to the GERD. However, insights from the application of the different analytic frames are discussed next.

8.6. Historical analysis frame

The analysis in Chapter 4 used historical evidence and reasoning to examine different events and treaties. It also provided a detailed literature review with a comprehensive summary of all the treaties in descriptive form and chronological order. Then, it adopted a politico-historical perspective to examine the treaties and provide an impartial perspective of the GERD dispute.

From this analysis, the researcher found that the Nile's treaties have remained partial rather than comprehensive, creating deadlocks in the matter of how to share the Nile's water. Co-operation is required to develop strategies for sharing information and dealing with uncertainties, and thereby find a mutually agreeable solution to the deadlock.

8.7. Legal analysis frame

The legal analysis frame was presented in Chapter 5. The interpretations of international water law and principles are of crucial relevance to this dispute. The main three international transboundary water laws - the HRs (1966), UNC (1997), and BRs (2004) - are an essential reference for understanding the legality of different states' actions with respect to water resources. Three disputes with strong similarities to the Egyptian-Ethiopian dispute - Gabčíkovo-Nagymaros Project, Botnia UPM Pulp Mills on the River Uruguay, and the BHPP – have used international water law to solve these disputes, so a comparison with the Egyptian-Ethiopian dispute is provided.

The legal analysis frame revealed the dominant behaviour running through the Egyptian-Ethiopian dispute has been unilateral actions by Ethiopia causing harm to Egypt. Disapproval of the downstream countries and their endeavours to seek both a negotiated solution and subsequently independent arbitration have not discouraged Ethiopia from continuing to take unilateral actions when constructing and filling the dam three times. The timing of some of these unilateral actions appears to suggest deliberate defiance. The absence of a pre-existing agreement between Ethiopia and downstream countries Sudan and Egypt concerning the Nile's management independent of any project using the water, such as that exists between Egypt and Sudan, may partly account for Ethiopia's intransigent position.

8.8. PIM frame

In Chapter 6, the PIM frame rated and evaluated the expected risks of the GERD. This analysis highlighted that all participants, except for two, could not see the major possibility of the occurrence of positive opportunities for Egypt from the construction and operation of the GERD. Most of them said that even if there is any positive impact it would be insignificant. Only two participants thought the GERD offered opportunities to Egypt; they came from countries standing to benefit significantly from it.

In contrast, the largest block of the participants classified the threats to Egypt as high priority and important to be dealt with. They evaluated these negative threats as almost certain to happen with catastrophic impact. The second group of participants classified the threats as medium level, whilst the two participants from the stakeholder countries were the only ones to classify the threats as low. No one classified the impact of these threats as very low impact. Together this analysis provides important insights into the perceived importance and the high priority of threats while showing the insignificance of opportunities.

8.9. Decision-making frames (decision trees and decision tables)

The decision-making frames in Chapter 6 highlighted the chance/uncertain nature of the situation and helped in evaluating new alternatives. A series of alternative actions were proposed for participants to assess, and these were analysed using decision making under conditions of risks and decision making under conditions of uncertainty.

8.9.1. Decision making under conditions of risks

The decision alternatives were portrayed using a decision tree, while EV was used to analyse the data and choose between alternative actions.

The analysis here suggested the *Prepare* decision as the best decision to be made by Egypt (80% of participants), while the *Continue Negotiations* decision alternative came second (with 10%). However, the analysis concluded that the Egyptian preparation should be done secretly so as not to affect the Egyptian position in negotiations.

The analysis also indicated that 70% of participants saw the decision of going to *War* as the worst and most risky decision, while another 20% thought that *War* was not even an option because of its catastrophic consequences. Next in order as the second worst decision was to *Do nothing.*

The analysis eliminated the Ethiopian's outcome of "not to fill the dam's reservoir at all". The participants considered it completely illogical, except in the case of sparking a war.

A new decision alternative was suggested, namely, to deduct non-uniform portions of water annually from the Nile to fill the GERD's reservoir based on the Nile's flow. That means that the pace of the filling process would vary in different years.

8.9.2. Decision making under conditions of uncertainty

Decision payoff tables were used as a tool to collect the data at interviews. Five different criteria were used to analyse the data: Maximin criterion, Maximax criterion, Hurwicz's criterion, Laplace's insufficient reason criterion, and Savage's Minimax regret criterion. These criteria represent different attitudes to risk and apply to a one-off decision.

This frame revealed that "preparation" and "negotiation" are the best decisions for Egypt in the view of the interview participants. "Do nothing" and "start a war" are both unacceptable as they are too costly in the long run. The analysis prompted two new decision alternatives: combining the preparation and negotiation decisions, i.e., for Egypt to prepare for this serious situation, whilst continuing negotiations with Ethiopia; and calling on the UN and different international entities to intervene or mediate and to urge the UN to back calls for a binding deal with the Ethiopian party.

8.10. TOC frames (TOC TPs and 5FS)

In Chapter 7, a suite of TOC frames was presented. The next sub-sections present key findings for each of the TOCs' tools.

8.10.1. Goal Tree (GT)

The main goal in our case was to ensure Egypt's survival. This goal was articulated without losing focus on the bigger picture involved in this situation. The CSFs to achieve this goal were to ensure human well-being, a successful economy, and improve Egyptian agricultural performance. It was also required to maintain employment levels in order to have a successful economy and human well-being, as well as adequate food production (to supply people's needs and export).

The analysis suggested that if we want to improve the Egyptian agricultural sector performance, we must have efficient/effective agricultural and water management practices; maximise the water and land unit productivity; and have an effective governmental agricultural policy framework. Moreover, the analysis showed that in order to maintain the Egyptian employment levels, there must be more employment in other economic sectors and an increase in the land available for agriculture to match population growth.

What emerges from the analysis here was that the goals and subordinate goals for managing the risks to Egypt's water supply were not met because most, if not all, of the CSFs and NCs, were not achieved. The first question "Why change?" was clearly answered after the analysis and findings of the GT.

The researcher noted how this research started by looking at Egypt's water supply and it developed into looking at Egypt's survival. This is due to the fact that the Nile is the only water resource for a population of approximately 110 million. Hence, the Nile is a matter of life and death for Egyptians because of its crucial significance to the nation, which makes sense to be closely connected to Egypt's survival.

8.10.2. Current Reality Tree (CRT)

CRT was then used to state the symptoms that arose from the underlying core problem(s). A sequence of RCs was mapped out and then the UDEs, which represent the symptoms, were clarified. These UDEs limit the achievement of the overall goal and could be traced to one core problem. A big CRT was created, based on the participants' comments.

The CRT started with a long list of UDEs in the Egyptian agricultural sector in the current situation before filling the GERD's reservoir or operating it. This tree traced these symptoms back to a number of RCs which combine to prevent the achievement of the main goal relating to the Egyptian agricultural sector, as was revealed using the GTs. The subordinate goal, in this case, was to "improve the Egyptian agricultural sector performance", which consequently affected the main system goal "Ensure Egypt's survival."

The main RCs were identified as: Egypt's current water poverty, population growth, lack of political will, support, vision, and leaders to support the agricultural sector that is displayed by the Egyptian government, the fragmentation of agricultural landholdings problem, and the climate change and global warming that affect Egypt. These RCs led to serious UDEs at the top, such as: ineffective/ inefficient agricultural management practices, water losses, limited land, and water unit production, etc, and finally the underperformance of the system. These RCs need to be changed to stop the UDEs and achieve our goal.

8.10.3. Conditional Reality Tree (Cond. RT)

The development of this tree is one of the significant contributions of this study. The Cond. RT studied the UDEs in light of the expected risks to Egypt's water supply due to the GERD. This tree resulted in diagnosing several RCs leading to the expected UDEs that have a high impact on achieving the main system's goal, "Ensure Egypt's survival".

The main RCs of UDEs expected under the GERD is that the amount of the Nile's water annually is (expected to be) cut by Ethiopia to fill the GERD's reservoir, which would lead to a decrease in the water volume at the Egyptian borders and reduce the water level in the AHD reservoir. Consequently, using the Nile as a water resource will need adjustment. Severe environmental impacts and consequences will happen, in addition to the huge damage expected for the agricultural sector, accompanied by an urgent need to find new water resource alternatives. These RCs led to more serious UDEs at the top. The analysis suggested that severe UDEs are expected to happen, which would seriously threaten regional security and stability.

8.10.4. Evaporating Cloud (EC)

The ECs helped in generating creative solutions for this dispute by addressing the assumptions underlying the necessity links that when broken, ‘evaporate’ the cloud. After some investigation to try to piece the ideas together, the researcher discovered that they followed a specific pattern and could be categorised under three main themes. These three themes are problems related to the agricultural sector; problems related to the expected risks to Egypt due to the GERD; and problems at the national level. In our case, the complete EC consisted of three consolidated cloud diagrams, in which their three generic EC were the core conflict cloud for the overall consolidated cloud diagram EC, as seen in Figure 34, Chapter 7. The 3-generic ECs of the three consolidated cloud diagrams led to the core conflict cloud represented as the overall EC, whose main objective was the main objective of our GT, “Ensure Egypt’s survival”.

The analysis suggested that in order to ensure Egypt’s survival, we must improve the Egyptian agricultural sector, minimise the risk effects of the GERD on Egypt, and maximise Egyptian economic welfare. Using the ECs led to creative solutions. For example, EC5, whose goal was to “maintain the Egyptian electricity production”, addressed the UDE concerning “the reduction of the generation of the hydropower of the AHD”. EC5 revealed creative solutions for this problem, such as buying electricity from other countries, finding new alternatives to generate electricity, or using other renewable energy sources to generate electricity.

The ECs not only revealed the hidden problems and conflicts of critical RCs discovered from the CRT and Cond.CRT, but it also revealed solutions for their UDEs. ECs showed that such a dispute could be addressed without compromises. The ECs’ solutions perfectly served the goals that were determined in the GTs as well as stopped the UDEs that were revealed by the CRT and Cond. RT.

8.10.5. Future Reality Tree (FRT)

Three big FRTs were created to answer the third question “What to change to?” FRT1 was used to answer the question regarding the current situation of the Egyptian agricultural sector, while the FRT2 and FRT3 answered the question in light of the expected risks to Egypt’s water supply due to the GERD in the near future, through two different scenarios/assumptions.

The results of FRT1 found that all proposed solutions would improve the status quo of the Egyptian agricultural sector and bring about the DEs., Table 30, Chapter 7, showed how these injections turned the UDEs into DEs. Moreover, no further negative side effects of these solutions were foreseen if implemented.

FRT2 presented the forecasted picture of “What to change to” in light of the expected risks to Egypt’s water supply due to the GERD in the near future. The underlying assumption, in this tree, is a new Egyptian-Ethiopian bilateral agreement, which regulates the rules of the filling and operating process of the GERD at a slow pace, taking place. Therefore, this slow pace would not affect the

Egyptian Nile's water share that much. The proposed injections/solutions, in this case, were three main solutions.

The results of FRT2 were found to improve the expected reality in light of the expected risks to Egypt's water supply due to the GERD in the near future could be achieved by maintaining the status quo. That is the reason for having only three main injections, for this tree, one of them is the main key to keep the situation controlled as it is now. The main injection here is "Egypt has an agreement with Ethiopia to fill the GERD over a very long timeframe, which will not affect the water's quantity or quality". This injection defuses the conflict, which would address the rest of the expected UDEs and turn them into DEs.

FRT3 works in the same situation as FRT2. However, the starting premise here is the failure of the bilateral negotiations and the Egyptian need to find water resource alternatives. The FRT checked what would happen if the solutions yielded from the analysis of the participants' answers and the application of the ECs were implemented, by using 19 proposed injections/solutions.

These injections were clustered into three groups (section 7.2.4.2.2). The first group was concerned with injections mitigating the impacts of the GERD on the irrigation and agricultural sector. The second group was concerned with injections mitigating the impacts of the GERD on electricity generation, agro-industries, and the increase in the unemployment rate, while the third group was concerned with injections enhancing the general government performance. It could be stated that FRT3 offered a comprehensive solution to mitigate the expected risks to Egypt's water supply due to the GERD in the near future, under only one precondition, which was finding other water resource alternatives.

The research also revealed a lack of interest of participants in environmental impacts because of the dominance of the GERD. These impacts were overlooked because they were not urgent in the short term. The long-term threats posed by environmental impacts seemed less important to the participants, in comparison with the urgent and immediate threats they currently suffer.

8.10.6. Prerequisite Tree (PRT)

In this study, two PRTs were constructed to work on the expected obstacles, the first focusing on the Egyptian agricultural sector, the second tree addressing the expected obstacles that would block Egyptian survival chances because of the risks to Egypt's water supply due to the GERD.

The first PRT clarified the obstacles that could block the Egyptian agricultural sector from meeting the nation's needs now and, in the future (the required target). Then it identified the sequence of actions needed to overcome these obstacles, IOs, as previously shown in Table 33, Chapter 7.

The recommended IOs are simple, practical, and cost-free, except for one IO (IO6a). However, these IOs needed high commitment, determination, and willingness to display strong political will, support, vision, and cadres (leaders) to support the agricultural sector by the Egyptian government. The only costly IO

(IO6a) related to finding new water resource alternatives was the only effective IO that could truly help solve the problem of Egypt's water poverty.

The second PRT identified the obstacles that could block the achievement of the main goal of our system, which was to ensure Egypt's survival in the case of the risks to Egypt's water supply due to the GERD. The sequence of actions was identified to overcome these obstacles, as previously shown in Table 34, Chapter 7.

The IOs proposed were the fastest, easiest, and most effective IOs to get the job done. They also produced the least possible collateral side effects; however, they were not cost-free because of the nature of the problem. This could be seen through some examples, such as: Egypt changes its economic policies, plans, and shifts to new industries (IO5c); Egypt imports crops from international markets (IO5a); and Egypt uses other renewable energy sources to generate electricity (solar plants) (IO17a). However, the required costs to fund these IOs were suggested through other IOs, such as: Ethiopia pays for constructing new renewable energy plants (IO16a), or costs of new renewable energy plants are funded by international funds and entities (WB) (IO16b). Again, high commitment, determination, and willingness to display strong political will are needed as well as adopting effective negotiation techniques to get Ethiopia on board.

Each PRT offered a comprehensive implementation framework that can serve as an action plan. These action plans clarified the identification of the expected obstacles and the IOs needed to overcome them. Therefore, decision makers in Egypt should consider using the PRTs to guide actions now and in the future, to improve the agricultural sector in particular, and the Egyptian position in general.

8.10.7. Five focusing steps (5 FS)

The 5FS provides a step-by-step continuous improvement process to address a system's underperformance. In this study, the application of the TOC 5FS framework provided a systematic set of actions to solve the problem.

Step 1: IDENTIFY the system's constraint(s)

Based on the field study, all participants identified the currently insufficient amount of water, which is expected to be much less during the filling process and operation of the GERD, as the studied case's constraint. Lack of water was unanimously considered by research participants as the weakest link that limits the improvement of the Egyptian agricultural sector in particular and threatens Egypt's survival in general. The research identified this as a physical, material constraint originating outside of the system, which makes it difficult to control.

Step 2: Decide how to EXPLOIT the system's constraint(s)

Exploiting the constraint means deciding how to get more out of the existing constrained resource, water. The 5FS analysis recommended four main avenues to improve the constraint's performance without additional resources. First, the participants suggested using more effective and efficient irrigation systems. There is currently a 50% loss in irrigation water due to inefficiencies. Second, the research showed that managing the agricultural process effectively could save a lot of water, such as choosing the right crops to grow, enhancing agricultural practices, etc. The third was to rationalise water consumption, while the fourth was managing the Nile's water effectively.

Step 3: SUBORDINATE everything else to the above decision
The research showed that other resources should be used differently to aid the constraint, so the constraint is more productive. For example, changing irrigation systems and managing the flow and usage of water for agricultural and domestic purposes.

Using some of the water stored at the AHD's reservoir could be another way to subordinate other resources to the constraint by applying the Drum-Buffer-Rope method. In manufacturing, DBM generates improvement by ensuring a buffer of work in front of the bottleneck, prior to the drum, to ensure that the constraint never runs out of work. DBM could work to some extent by using the AHD as a buffer, but it could not completely cover the expected water shortage due to the GERD.

Step 4: ELEVATE the system's constraint(s)
The research stated that steps 2 and 3 alone are not sufficient to eliminate the constraint. At this point, however better the constraint's performance is, it is still not enough to cover the required demands. Therefore, the constraint needs to be elevated by increasing its capacity. Further actions are needed that will cost, such as developing new strains of crops that can grow with less water, expanding the use of greenhouse technology, and investing in finding new water resource alternatives.

The suggested alternatives include rain and floods; groundwater; waste water and sewage recycling; seawater desalination; and establishing connections to water supplies in other countries. However, Egypt has generally very low annual precipitation rates, which usually do not exceed 1 bcm. Moreover, rainwater is not available everywhere in Egypt, only in certain places and cities.

The Nubian Sandstone Aquifer System (NSAS), the world's largest known fossil water aquifer system, could be used as a groundwater source. However, some participants warned that this reservoir is limited as a non-renewable resource, and its location is challenging, which makes the cost of transporting its water so expensive as well as the cost of pumping the water to the surface. They also favoured conserving the NSAS for future generations.

Another suggestion was to use recycled waste water to grow forests and non-food crops used to produce goods for manufacturing, such as fibre for clothing, printing ink, and paper coatings to ensure maintaining good human health.

The analysis showed that the cost of seawater desalination is too expensive to use as an alternative water resource for agriculture. It could only be used for household and industrial purposes. Moreover, this alternative is an energy-intensive process, which makes it difficult to be used right now, especially with the electricity supply from hydropower is also under pressure with reduced water in the Nile.

Few participants suggested establishing or connecting to water networks in other countries. These would require new cooperation agreements and expensive capital projects. For example, a huge dam on the Congo River could be constructed to generate electricity or to store water that could be used for growing crops, or an Egyptian-Ethiopian bilateral agreement under which Ethiopia, which has generous rainwater and lake water resources, could sell water to Egypt at reasonable prices.

Step 5: WARNING! If in the previous steps, a constraint has been broken, go back to step 1, but do not allow INERTIA to cause a system's constraint
The 5FS keeps our eyes open for new constraints, as a process of ongoing improvement. New constraints will emerge after breaking the old one, which makes it important to go back to step 1 and be aware of inertia. Once a new constraint is identified, it should be managed or eliminated. This step cautions us not to get so comfortable after dealing with the first constraint because this cycle never ends, and a new constraint must be addressed unless the constraint is in a place that makes the system easier to control.

8.11. Towards a solution: Finding the synergy between the frames

After this complex situation was analysed and studied in greater depth, now I can see that, if possible, Egypt must take an amicable approach to encourage Ethiopia to play its part in solving this problem. The researcher believes that the solution should follow two parallel paths.

The first path involves Egypt finding other ways to make Ethiopia an offer that cannot be refused. This offer should be with terms so attractive that it is almost guaranteed that Ethiopia would accept it. Ethiopia has been building the GERD for two main reasons. The first is to generate electricity for national use of electricity (households and different sectors). The second is to sell hydropower to increase and stimulate the country's economic growth.

One of Ethiopia's concerns relates to keeping the GERD running in the dry season so it can discharge both obligations. However, in a situation where the reservoir's filling coincides with the dry season, Ethiopia will not be able to keep water flowing to Egypt while filling the GERD's reservoir. I will first assume that Ethiopia will postpone the filling of the GERD during the dry season. There are several options to help Ethiopia overcome the expected reduction in generating electricity at this time, assuming that both parties in this dispute behave rationally and that they want to solve the problem.

Egypt could sell Ethiopia electricity or build some non-hydroelectricity plants to provide the deficit in Ethiopia's power-generating capacity during such periods for their national use and to cover its contractual agreements to supply other countries, provided Ethiopia allows what water is available to flow freely. Additionally, Egypt could offer to create a joint agricultural integration area in Ethiopia, develop a free trade and/or agricultural agreement, construct new road networks across the boundaries, and/or establish new plans to maintain food security. Egypt should include in such proposals that Ethiopia could keep a greater share of the profits. The common economic interests and profits here would be compensation to Ethiopia to cover the reduction in the hydropower sold. In exchange, Egypt gains greater control than under the current situation where Ethiopia acts unilaterally.

The second parallel path assumes that Ethiopia will continue filling the GERD's reservoir during the dry season or in general at a fast pace. Egypt should find other ways to adopt a few positive ideas to de-escalate tensions and find temporary water resource alternatives. First, connecting the Nile with other water networks could be significantly helpful. The Congo River, for instance, is the second largest river in the world by discharge volume after the Amazon. Connecting the Congo River to one of the Nile's tributaries would be feasible technically without depriving the Congo basin states of water. Cooperation through a new international agreement would be required. This would help in increasing the volume of water in the Nile, while constructing a small dam to store water and generate electricity. The generation of this electricity could be managed in the interests of Ethiopia during the dry season to cover the deficit in hydropower generation to meet their contractual obligations to supply other countries.

The EU's partnership could also be useful, especially as they are the main importers of Egyptian crops and Ethiopian meat. The EU could help fund the water projects, and the costs of pipelines to connect the Congo River to the Nile to help solve this dispute. However, Congo should be benefitted as well from such an arrangement. Substantial additional investments are required to enhance the situation in this poor country and accelerate progress.

Another solution could be the temporary use of the groundwater at the Nubian Sandstone Aquifer System (NSAS). However, groundwater is a non-renewable water resource which should be used with great caution and conserved for the next generations. Another temporary solution is to use some of the water stored in the AHD's reservoir, which could act as a buffer for some time to partially overcome water shortages. However, that could not cover the whole expected water shortage.

International support is still required to overcome all these challenges.

This recommended approach fits with the guidance of the PIM, decision trees and tables frames, which showed that the best choices for Egypt to ensure its survival are to prepare while continuing to negotiate, and de-escalating tension to avoid war. This approach also draws on the signed treaties and agreements over the Nile and international water law and principles of no harm and fair, equitable share. It also acknowledges the Ethiopian pattern of not signing the current agreement related to the regulations of GERD and acting unilaterally. This pattern could be explained as normal behaviour for an upstream country in favouring the principle of "Equitable and reasonable utilisation" and arguing it has not had its fair share in the past. This principle also allows them the immunity and flexibility of using their water share, whatever the impact on downstream countries is. This approach combines the results of the different frames of the study and works to integrate them all to find a solution that can defuse this tense situation.

8.12. The analysis of participants' perceptions of the data interpretation and meaning-making processes

As explained in Chapter 3, the existing literature and interviews were the data sources for this research. Primary data collected for this research was through the participants' views to capture different and multiple evidence and proofs. Given the nature of the research and the type of concepts examined, this primary data helped in serving different purposes, as will be illustrated in this section.

Primary data was collected by the researcher as required for each specific frame. This process was costly, time-consuming and much harder due to the Covid-19 pandemic. However, the data collected via interviews played a significant role in answering the research questions. The questions of these interviews were specifically designed for the research. Interviews were held in English and Arabic at different levels. It is important to explain how participants' perceptions affect the data interpretation and meaning-making processes.

This section reviews first how the multi-framing was applied based on the participants' levels, backgrounds, and nationalities. Then the depth of complexity captured based on the perceptions of different participants and stakeholders is discussed. Lastly, the nature and implications of the revealed problems are discussed.

8.12.1. The multi-framing captured in context based on the participants' levels, backgrounds, and nationalities

In this study, structured interviews were used, with questions separated into five sections. Participants were asked subsets of these questions. The perceptions expressed varied according to the participants' levels, backgrounds, and nationalities, as was explained in Chapter 3, Table 5.

The researcher noted that the perception expressed by the two participants from UpC at the analysis of the PIM frame was questionable, where their results in evaluating the opportunities and threats to Egypt due to the GERD were extremely different from the rest of the participants. These results, unsurprisingly, showed potential bias due to their countries' positions. The results of the two participants showed the highest evaluations for opportunities to Egypt due to the GERD, while showing the lowest evaluations of threats.

The researcher believed that a participant from Egypt also showed potential bias, evaluating the likelihood and criticality of threats as low. The researcher suspected that this participant's answers were more diplomatic than truthful, because of their position as a politician and former government official.

The analysis of participants and stakeholders helps not only in identifying who the stakeholders are and what they are seeking to achieve but also in revealing possible conflicts of interest.

8.12.2. The depth of complexity captured

The participants were representative of stakeholder groups from both within and outside Egypt, and from national, government and industry leaders right through to individual farmers.

The depth of complexity captured varied depending on the perceptions of these different participants and stakeholders. The complexity also depended on the frame used and the questions asked. Some participants and stakeholders were concerned with the practical details while others took a broader policy perspective.

The depth of complexity captured was not affected at the international level by the perceptions of participants, except for the bias mentioned above, which generally was not related to the depth of complexity.

However, the researcher concluded that one aspect relating to the depth of complexity captured was overlooked during the national-level interviews, when, surprisingly, none of the participants discussed the environmental impacts of the GERD as expected dilemmas when answering questions related to the ECs, or even tried to find solutions to overcome their consequences, although they had discussed them prior as UDEs of the GERD. The researcher found that the current threats the participants already suffer in the short term are considered to be urgent and catastrophic, in comparison with the threats from environmental impacts which are possibly perceived to be longer-term and therefore less important. Participants at the national level were feeling afraid and threatened because of the short-term effects due to the GERD more than the long-term effects, which made them overlook some of the important effects in the long term due to their more urgent survival needs.

However, it also could be argued that this is a result of the EC being a powerful focusing tool that encourages tunnel vision. The participants were totally focused, perhaps to the detriment of keeping a wider vision, when they were asked about the dilemma(s) from their viewpoints. This could be explained based on the nature of the TOC's analysis, which becomes progressively more focused throughout the TOC TP cycle.

8.12.3. The nature and implications of the revealed problems

The nature and implications of the revealed problems differed depending on the background and experiences of different participants and stakeholders. This was extremely obvious at national interviews because of the wide variation in participant backgrounds. GTs, CRTs, and PRTs will be used here to illustrate.

The problems revealed by participants belonging to the governmental/national category (NL) reflected their concerns regarding the 'bigger picture'. They discussed **high-level goals** such as an Egyptian economic shift; increasing water unit productivity; increasing the land unit productivity, while they discussed **RCs** for the current situation such as climate change, rapid population growth, and cultural and behavioural long-standing practices and traditions, along with **UDEs** like water wastage and low crop production that arise as a result.

The problems revealed by participants belonging to the local category (LL) were more pragmatic and more concerned with details. They discussed **goals** such as employing effective and efficient land use, the land reform law, and sufficient water supply, while the **UDEs** they discussed included the low efficiency of Egyptian irrigation and drainage, wrong agricultural practices, and fragmentation of land holdings.

The problems revealed by participants belonging to the third category, the industry category (IL), were more concerned with the industry itself. They discussed **goals** such as using new advanced technologies (hoop houses, and vertical farming), applying good industrial practices, and ensuring investment. They discussed black markets, rampant corruption, and excessive use of fertilisers as some of the **UDEs** of concern.

The obstacles discussed with respect to PRTs varied based on each individual category as well. Participants belonging to the NL discussed obstacles such as: the rapid increase of the population, and the long-standing wrong practices and traditions that waste water. Some participants belonging to the LL said that there is not enough water to irrigate their lands, while some participants belonging to the IL category talked about the ineffective Egyptian irrigation methods and the unavailability of strains for less water-intensive crops. These obstacles were fully consistent with the RCs identified in the CRTs.

This research concluded that the wide variety of backgrounds and experiences of different participants and stakeholders have greatly enriched the input, analysis, discussion, and outcomes of this study. They also reflected the nature and implications of the problems revealed at different levels, which allowed the study to delve into the issues, cause-effect relationships, and the variety of problems caused by the GERD.

8.13. Multi-framing as an analytical approach

As explained earlier, the use of the multi-framing approach for complex problems in which a single frame is inadequate has been recommended by several authors (Bolman & Deal, 1991; Mabin & Davies, 2004; Tengblad, 2012). This section discusses the use of a multi-framing approach in this study. It describes how it was used, shedding light on the perspectives each frame covered, the methods/tools used, contributions made, what was highlighted by each tool, and what was shadowed by each tool.

8.13.1. Different frames and perspectives communicate different facets of complexity

As a general methodological observation, the researcher noted that applying each frame helped put things into perspective, revealing different aspects of the complexity of the issues faced, which, when combined, exposed the bigger picture.

The efficacy of the multi-framing approach can be seen in terms of the nature and depth of complexity exposed, which in the context of this study, revealed different aspects of complexity embedded in the agricultural sector in Egypt and the situation related to the GERD. The study also showed that certain levels of complexity were easier to depict than others based on the frame used. It is interesting to note that whereas the historical frame, for instance, captured complexity in a way that characterised the historical context of the problem, the TOC frames helped to add more structure to the current and future situations of the problem. The next section will explain how different perspectives and frames communicated different faces of complexity.

Using the multi-framing approach allowed us to communicate those perspectives in ways that differed from one frame to another. Each of these aspects is discussed in turn.

8.13.1.1. Historical analytical frame

The historical frame analysis presentation simply mirrors the complexity of the chronological order of events and treaties between Egypt and Ethiopia in a more descriptive sense by using a literature review that provided a comprehensive summary of all the previous treaties that have been negotiated, as an essential foundation for understanding the current dispute.

This historical frame focused on documenting the bonds between Egypt and Ethiopia evident in historical evidence and treaties to crystallise the views of both parties. For instance, the discussion of the DoP agreement that was signed between the three countries, Egypt, Sudan, and Ethiopia, about the GERD was significant in showing not just the areas of disagreement, but also the principles that were agreed upon by these countries. However, this perspective has not suggested how to resolve the current situation or foreshadow the future.

8.13.1.2. Legal analytical frame

This frame offered a more systematic, well-structured process for communicating complexity by adopting the legal perspective. It describes the situation of the dispute against the background of international water law principles and relevant case law to clarify the legality or illegality of actions, conditions, or intent for both countries. Relating this to the Ethiopian unilateral actions in diverting the Blue Nile to start constructing the GERD and filling the GERD's reservoir three times, the illegality of actions and questionable intent of Ethiopia became apparent.

The frame highlighted unilateral actions by Ethiopia as the dominant behaviour that has defined the Egyptian-Ethiopian dispute, related to the GERD. This frame provided legal background to the dispute and enabled the researcher to use this legal view to help clarify the current situation.

8.13.1.3. PIM frame

Likewise, the PIM frame, added another angle to analyse the complex issue. This frame offered an understanding and evaluation of the risks associated with our case study.

The complexity revealed by this frame allowed the researcher to appreciate the issues and challenges faced by Egypt due to the GERD. A notable issue, and one of the study's questions, relates to evaluating the nature of the situation and determining the risks involved, for which the PIM frame analysis helped in providing deep insight. This frame suggested that the threats to Egypt because of the GERD were serious, while on the contrary, it showed that opportunities claimed in the literature were insignificant compared to the threats.

8.13.1.4. Decision trees and tables frames

These frames exposed deep insight into the situation and created new decision alternatives the researcher was not aware of. For instance, it suggested deducting non-uniform portions of water annually from the Nile to fill the GERD's reservoir instead of storing a fixed amount. The frames put forth the idea that Egypt should call on the UN and different international entities to intervene or mediate and to urge the UN to back calls for a binding deal with the Ethiopian party.

The researcher observed that perceived complexity can be reduced by excluding weak decisions. The frames eliminated weak decisions, such as the war decision which would be costly, in favour of decisions that would be more beneficial to Egypt. The frames provide insight into combining different decision alternatives. Such insight prompted the researcher to think that the preparation decision and the negotiation decision could be taken in parallel.

However, it also should be mentioned that the decision trees and tables frames can only handle a small number of discrete alternatives, and they shadow the in-between options – such as letting the tension escalate until it turned into conflict (war).

8.13.1.5. Theory of Constraints analytical frames (TOC TPs and 5 FS)

The researcher noted that TOC framed the complexity in a different sense. TOC was guided and underpinned by using logic protocols. In the context of this study, a range of TOC TPs tools besides the 5FS were used. Each tool communicated complexity differently, using different protocols based on the purpose of the tool and the logic it used. The researcher gained more understanding and insights about the studied problem, cause-effect relationships, and solutions by using TOC frames and tools, as they unfolded the ambiguity of the situation.

The researcher observed that the contribution of the TOC frames varied from tool to tool; however, all tools worked together in sequence to diagnose, analyse, suggest, and test solutions. GTs contributed to determining the system's goal, and its required CSFs and NCs for success. CRTs analysed the current and expected situation and then clarified its UDEs to focus on what needs to be changed. ECs generated win-win solutions, evaporating each dilemma/conflict by breaking its assumptions through new injections (proposed solution ideas). FRTs checked the best of these proposed solutions to ensure that they would really work including devising strategies (or adding in extra injections) to avoid potential negative side effects, if any. PRTs clarified the obstacles that could block the target's achievement and generated the sequence of actions needed to overcome these obstacles. Finally, 5FS improved the output of our system by clearly identifying our constraint and focusing efforts to get more out of it.

The CRT captured the complexity by defining a range of RCs and mapping the logical connections, which led to a better understanding of the situation as described by the interrelationships between RCs and UDEs. Particularly, the analysis showed that the nature of cause-effect relationships and the complexity of the issue represented by the CRT were totally underestimated by the literature. The CRT shed light on a better explanation of these cause-effect relationships that contribute to the overall UDEs, which improved the researcher's understanding of the issues limiting desirable outcomes for the agricultural sector in Egypt.

Working on the second CRT led to a bigger discovery. To map our coming reality, the researcher had to make a new development of the tool itself to capture the situation.

The CRT as a tool, in general, works only on a reality that already exists. However, in our case, that was not completely true. The second tree represents a conditional situation that is almost real. The construction of the GERD is almost finished, while Ethiopia already has cut small portions of the Nile's water three times to test its turbines. It is a matter of time before it will start filling and operating the GERD. This tree analysed the expected RCs of this expected conditional situation, based on the participants' opinions relating to the expected UDEs in the case of the GERD operation.

Generally speaking, the TOC TPs tools follow two types of logic. Some of them follow the "necessity logic", while others follow the "sufficiency logic". However, there was a need to combine these two logics during the development of this new tool. The Conditional Reality Tree (Cond. RT) works based on the two logics together.

First, the researcher applied the "necessity logic" before forming the tree itself. This logic is represented in the "in order to form the tree, the filling and the operation process of the GERD must be true." One action is necessary before the other can happen. The full-filling process must start first before the UDEs, shown in this tree, can happen. However, the condition, in this case, was not related to the logic applied during the constitution of the tree; it was the main condition assumed that underpins the construction of the tree itself. Without assuming this condition, the researcher could not start forming the tree. Second, the tree itself follows the normal "sufficiency logic" like the other reality trees, CRT and FRT. It works out all the RCs and UDEs regarding the expected conditional reality due to the GERD by using this logic.

A major advantage of using this new tool is that it combines the TOC's two logics perfectly. It is not appropriate to label it a current reality tree since the entities in the tree do not yet exist, but they are expected to exist if the starting condition comes to pass. However, it is also not appropriate to label it a future reality tree, as it represents an undesirable situation, so it is better referred to as a Conditional Reality Tree. The researcher noted that the newly developed tool, Cond. RT helped in working on the soon-to-be-expected situation by clarifying the expected UDEs due to the GERD. The new tool is ideal for explaining an expected conditional reality. Therefore, it is ideally suited to situations that represent impending disasters such as climate change/global warming, population growth, or intensification of war/conflict.

In general, the researcher found that using the CRT helped to develop more clarity about the relationships, and in particular, enabled her to separate UDEs and RCs that had been intermingled in the comments of the participants. Putting all the pieces together when building the CRT helped the researcher to notice more UDEs than the ones that were mentioned by participants. The main purpose of the CRT is to determine the RCs which then allows a focused effort to eliminate them, which was also achieved through its analysis.

It is also worth mentioning that in this study many of the TOC TPs were used in a different way than standard practice. However, the new practice was adapted to suit this studied case. However, the researcher felt it was sensible and effective in this situation. For instance, PRT had to be relaxed to allow future obstacles, not just current ones, which is different from the standard case in using PRTs. Additionally, in FRTs, multiple injections were used, rather than a primary injection and adding supporting ones which is standard practice.

The researcher believed that using the TOC helped in providing a more focused understanding of the different aspects of this situation. TOC offered the inspiration for presenting applicable solutions as well. Such clarity in understanding conveyed by the TOC TPs would have been impossible to achieve otherwise.

The TOC analysis and different tools allowed the researcher to have deep insights into this complex situation. The participants' views were all so valuable. They were each very familiar and lucid about certain parts. However, none succeeded to capture or see the whole picture. They all expressed their opinions that make sense from their respective levels and perspectives. The researcher has been able to piece their contributions together, all these seemingly unconnected bits of the puzzle, to make a coherent whole. Moreover, using different TOC tools helped to capture the rest of the picture and provide new RCs, UDEs, solutions/injections, obstacles, and IOs than were suggested by the participants.

8.13.2. Description of the multi-framing approach

In the context of this study, the application of the multi-framing approach gave the researcher a deep insight into the nature of the approach itself, which followed a specific sequence in order to maximise its benefits. The researcher observed that the multi-framing approach had specific characteristics, in which each frame was built on the previous one.

The assumption underpinning the multi-framing approach is that different frames allow us to see more aspects of the world. Some of these aspects were important to come first to represent the ground that the other frames are built on. Therefore, this particular order of frames was crucial for this study to maximise its benefits.

The researcher noted as well that moving between the frames helped interpret the problem in multiple ways, which created new decision alternatives and led eventually to different solutions. Moreover, it has broadened the understanding of the situation, developing complementary perspectives in different contexts as well. The results of this study will benefit the decision makers and different stakeholders in Egypt by explaining how the agricultural sector and the Egyptian water resources could be managed more effectively to improve outcomes for all stakeholders.

The researcher envisioned this sequence for the optimal implementation of this multi-framing approach by applying the different frames in a systematic, sequential manner to create complementary understanding and insights related to the risks to Egypt's water supply due the GERD on the Egyptian agricultural sector and Egypt in general. The researcher interpreted the data from one frame using insights from previous frames. The concept and implications of using the frames in the chosen sequence are considered next.

The researcher believes that this multi-framing approach contributed a novel methodology that will have implications for studying ongoing disputes over shared watercourses in general as will be discussed later.

8.13.2.1. Applying the frames in sequence

As a methodological observation, the researcher noted that typical examples of moving between different frames in a sequential and progressive way in this study could be presented by the sequential flow from the literature in the first two frames to interviews and personal experience in the other frames.

One obvious example of using the frames in a sequence is the movement from the historical frame to the legal frame. The historical frame discussed the historical perspective, in which all the Egyptian-Ethiopian treaties and agreements were debated. One of the most important agreements is the DoP in 2015, the agreement on the Declaration of Principles on the GERD, which is the only agreement that has been signed relating to the GERD. This agreement was one of the pillars used to work on the legal frame, which clarified the legality or illegality of the current actions of the two countries according to its Articles that stemmed from different international water law principles. The first two frames were mainly based on literature that explained the history of the conflict and then the current situation.

The study is also characterised by a sequential flow from the literature-based study to the field study that appeared in the third frame. This frame discussed the risk evaluation of the current dispute and situation, which was important to judge the seriousness of the problem to emphasise the importance of the ongoing search in finding durable solutions. The PIM frame prompted the researcher to see the world in terms of the severity and criticality of the risks.

Subsequently, the decision-making frames prompted the researcher to see the world in terms of competing interests, power, and influences of the two actors whose primary concern or success may depend on effectively managing the decisions and uncertainties involved. However, once decision analysis frames had been applied, the researcher began to see and think about the situation through different strategic behaviours, which maximised the benefits of the proposed decision alternatives.

Then with the switch to the TOC frames, the researcher was prompted to move on from the present and think strategically about the future, viewing the problems as symptoms of underlying RCs limiting the successful achievement of the desired goals in the future. The TOC analysis then focused on how to address such RCs, find solutions, and overcome the expected obstacles during implementation. While the TOC TP can be viewed as one frame, another example of using tools in sequence occurs within the TOC TPs, in which its five different tools have a specific order to follow. In the context of this study, TOC TPs are using the change sequence framework to answer five fundamental questions in order. It starts with the GTs, then CRTs, ECs, FRTs, and finally the PRTs.

8.14. The contributions and shadows of the multi-framing different approaches

Key insights relating to contributions and shadows (shortcomings/flaws) of the various analytical frames are summarised in Table 35.

Perspectives	Frames used	Purpose summary	Methods/tools used	Contribution	Shadows	Data source
Historical perspective	Historical analysis frame	Provide a the historical context of the situation	Uses historical reasoning to illustrate the bonds between Egypt and Ethiopia through different evidence, and examine the historical evidence and treaties to declare the views of both parties	Evaluate the effectiveness of the Egyptian-Ethiopian historical argument to make a full understanding of the past, which led to a better evaluation of the current situation	Does not suggest how to resolve the current situation or foreshadow the future	Treaties from literature
Legal perspective	Legal analysis frame	Provide legal background to the situation	The international transboundary water laws relating to the conflict between Egypt and Ethiopia over the Nile's water	Shed light on the legal view of the conflict; clarify the legality or illegality of actions, conditions, or intent according to different international laws	Does not help with the past and future situation	International water law principles and relevant legal cases from the literature
Risk perspective	PIM frame	Identify probabilities and severity of risks to show how bad the problem is	Probability and impact matrix	- Rate the risks based on their probability and impact - Evaluate and classify the importance of each risk	Does not help to solve the problem	Interviews and personal experience
	Decision trees frame	Evaluate the actions of the two players in a reactive phase to show what options are best	Decision trees and EV	Show the two players' actions when adopting a certain strategic behaviour	- Decision trees are deterministic and static - Uses EV which applies to repeated decisions - Handles a small number of discrete alternatives, and they shadow the in-between options	Interviews and personal experience
	Decision tables frame	Evaluate the actions of one player in a proactive phase to sequence events and uncertainties	Decision tables and 5 criteria	- Show the different kind of actions, which could be taken depending on the nature of the conflict and attitudes to risk aversion	- Not showing the other parties' actions - Difficult to capture multi-stage decisions	Interviews and personal experience

Perspectives	**Frames used**	**Purpose summary**	**Methods/tools used**	**Contribution**	**Shadows**	**Data source**
				- Useful for one-off decisions	- Handle a small number of discrete alternatives, and they shadow the in-between alternatives	
TOC perspective	The TOC frames, Thinking Process tools (TPs) analyse and resolve problems by using the "5 change question sequence"	Answer the first question "Why change?" by showing what the ideal situation would be	Goal Tree GT	-Determine the system's goal, CSFs, and NCs for the success - NCs that are not being achieved provide starting points for the next question, what to change	Quantitative aspects	Interviews and personal experience
		Answer the 2nd question "What to change?" by showing what reality looks like (the RCs of present and expected difficulties)	Current Reality Tree, CRT, and Conditional RT, Cond. RT	- Clarify the undesired effects of the situation - Identify RCs of the current and expected situation via cause-effect relationships - Focus on what needs to be changed	Quantitative aspects	Interviews and personal experience
		Generates a solution that starts answering the 3rd question "What to change to?" by revealing the conflict that is preventing the ideal reality	Evaporating Cloud EC	Focus on depicting the conflict-blocking solution using necessity logic to find ideas for a win-win solution	Sequences of events and uncertainties	Interviews and personal experience
		Answers the 3rd question "What to change to?" by testing and improving the proposed solutions	Future Reality Tree FRT	Used after the EC to check that the proposed solutions will really work including devising strategies to avoid potential negative side effects	Quantitative aspects	Interviews and personal experience
		Answers the 4th question "How to	Prerequisite Tree PRT	Identify obstacles blocking the		Interviews and personal experience

Perspectives	Frames used	Purpose summary	Methods/tools used	Contribution	Shadows	Data source
		cause the change?" by showing the steps required to overcome the obstacles		achievement of the target and generate the sequence of actions needed to overcome the obstacles	Quantitative aspects	
	TOC 5FS	Identifying and exploiting constraints	5 Focusing Steps 5FS	Stepwise process for continuously improving the output of a system by identifying constraints and focusing efforts to get more out of those constraints	Disadvantages of stepwise change	Interviews and personal experience

Table 35: Different perspectives and methods used to analyse risks to Egypt due to the GERD.

In the context of this study, none of the individual analytical frames could have individually achieved the necessary analytical depth, rigour, and precision to reveal the complexity surrounding this situation. The multi-framing approach proved to be extremely beneficial in this context. The multi-framing approach was implemented using different frames consistent with their individual and unique protocols, which complemented each other without overlapping.

The researcher noted that each approach/tool contributed to this research in a different way by covering specific areas; however, each failed to cover other areas. TOC, for example, helped in setting higher-level objectives for the system and provide a means for charting how appropriate actions could be implemented to reach this goal and resolve conflict in a manner that seeks a win-win solution. However, it could not provide a realistic analysis without the historical context of the situation. Therefore, it was important to use various frames to capture different aspects, given that no single frame is superior or designed to capture complexity holistically. This makes the multi-framing approach even more relevant for such complicated situations.

The researcher observed that none of the frameworks or tools was in conflict. On the contrary, they supported the findings of the other. For example, the findings of the two decision-making frames, decision trees and tables, were consistent. Both frames eliminated the same decisions, while highlighting the importance of the other decisions. However, they prompted new decision alternatives as well, which were then fed into the later analysis.

At the end, the contributions of all perspectives have been integrated to provide a means of solving this dilemma. The researcher noted that these perspectives are useful and should be used complementarily.

8.15. Different perspectives and approaches at macro and micro levels

In the context of this study, the researcher concluded that some of the frameworks used were applied at the macro level, while the rest were more concerned with the micro level. The macro level looks more at the bigger picture, which is presented at the international and national levels, while the micro level is more concerned with details of the agricultural sector itself and interactions between individuals. Macro and micro level studies, each have their own benefits and drawbacks. However, in this study, they holistically embraced the issue, as explained in Table 36.

Perspectives	**Frames /tools used**	**Level of study**	**The context that determines the level of study**	**To what extent it supported the other frames**
Historical perspective	Historical analysis frame	Macro level	It studied international treaties at the international/ macro level	- It supported the understanding of the historical context of the situation. This insight was one of the grounds to build on for the next frame
Legal perspective	Legal analysis frame	Macro level	It studied the legal situation of the dispute by using international water law principles at an international/macro level	- It supported the understanding of the legal background of the situation - It contributed to the bigger picture of the dispute at the macro level
Risk perspective	PIM frame	Macro level	It evaluated the risks based on international interviews at the international/macro level	- It identified the criticality and severity of risks, which proved high threats to Egypt's water supply - Based on its insights, the frame supported the importance of studying these risks through different decision alternatives to maximise the benefits and minimise the damage
	Decision trees frame	Macro level	It showed the actions of the two players in a reactive phase at the international/macro level	- The results supported the findings of decision tables
	Decision tables frame	Macro level	It showed the actions of one player in a pro-active phase to sequence events and uncertainties at the international/macro level	- The results supported the findings of decision trees

Perspectives	**Frames /tools used**	**Level of study**	**The context that determines the level of study**	**To what extent it supported the other frames**
TOC perspective	TOC (TPs) GT	Macro and micro level	It determined the system's goals to reveal the bigger picture at the national/macro level, as well as the goals of the Egyptian agricultural sector at the micro level	- The TOC (TPs) analyse and resolve problems by using the "5 change question sequence" - It answered the TPs 1st question "Why change?"
	TOC (TPs) CRT	Micro level	It clarified the UDEs at different levels. This tree was for the agricultural sector at the micro level	- It answered the 2nd question "What to change?"
	TOC (TPs) Cond. RT	Macro level	It clarified the expected UDEs at different levels. This tree studied the situation regarding the GERD at the macro level	- It answered the 2nd question "What to change?" in light of the expected risks to Egypt's water supply due to the GERD
	TOC (TPs) EC	Macro and micro level	Some of the ECs worked on generating solutions for the agricultural sector at the micro level, while some worked on the Egyptian national problems at the macro level	- It answered the 3rd question "What to change to?"
	TOC (TPs) FRT	Macro and micro level	3 FRTs were constructed. One depicted the agricultural sector at the micro level, while the other two depicted two expected scenarios for the Egyptian national plans at the macro level	- It answered the 3rd question "What to change to?"
	TOC (TPs) PRT	Macro and micro level	Two PRTs were constructed. One tree worked on the agricultural sector at the micro level, while the other worked on the GERD situation at the macro level	- It answers the 4th question "How to cause the change?"

Perspectives	Frames /tools used	Level of study	The context that determines the level of study	To what extent it supported the other frames
	TOC (5 FS)	Macro and micro levels	It presented the steps required at the national level/micro level, while it explored different options on the international/macro level as well	It is a process for continuously improving the output of the system by identifying constraints and focusing efforts to get more out of those constraints, which eventually helped in elevating the constraint

Table 36: Different perspectives, frames, level of study and its context, and the extent of support the frames offered.

In this study, the researcher believes that different perspectives and approaches have been integrated at the macro and micro levels. There was no evidence of conflict between any of these frames. These levels were defined based on the role of context, nature of frames, perspective, and level of analysis in the multi-framing processes, which led to developing deep insights and suggesting alternative actions. The nature of the dispute itself affected the nature of the application of the frames and tools in this study. The dispute is a political international dispute over a watercourse shared between several countries, where one country's actions are adversely impacting two downstream countries. We can see that the nature of this conflict was mirrored, for example, in employing the first two frames, historical and legal frames, at the macro level because this was an international dispute. The researcher asserts that the conceptualisation of the complementary nature of frameworks at macro and micro levels was proven to be reciprocal.

8.16. The multi-framing approach as a proposed methodology for studying international water disputes over shared watercourses

The nature and content of international water disputes are significantly complex. One-dimensional analyses of international disputes over shared watercourses, depending only on one or two perspectives, are not able to capture the complexity and would lead to limited scope and single-track assessments. Such analyses do not foster an adequate understanding of the situation and its RCs and limit the options open to consideration. Analyses of these kinds of disputes need to consider the many different aspects and impacts that affect the situation and outcomes.

With the use of multiple frames being a natural consequence of this need for more angles to be investigated, the question then is what sort of frames should be used, and how should they be combined. The analyses chosen here were historical, legal, risk, decision analysis, and TOC analysis, such choice/usage taking into consideration the theoretical and practical goals of the research and the nature of the conflict itself. They were chosen to suit the situation to understand the nature of the studied risks, identify the RCs, evaluate the expected risks, and create integrated risk analysis frameworks for decision makers. The four different perspectives together led to a better understanding. Moreover, they addressed the implications of the dispute. They identified, controlled, alleviated, and evaluated the consequences as well as suggested win-win solutions to both parties, if applied. This study benefitted from using these perspectives and frames to analyse the complex situation in Egypt due to the GERD. The order, while basically pre-planned, worked very well as the analysis evolved based on the nature of the studied case and according to the issues that surfaced and had been untouched by previous frames. Their use within a multi-framing methodology, rather than trying to create a multi-methodology, allowed the flexibility to harness complementarity without paradigm incommensurability.

This innovative methodology itself is a key contribution of this research. No similar study has been conducted elsewhere to study this dispute using multi-framing or the variety of perspectives, frames, and tools for the analysis. Additionally, prior researchers seem to have overlooked using many of these frames and tools in studying international water disputes. Some of the frameworks used in this study which proved to be significantly beneficial, such as TOC, have not (to our knowledge) been used before to study this international water dispute or any other international water disputes.

It is envisaged that this approach and the frames used will provide a methodological framework for other similar disputes over shared watercourses.

The researcher suggests that much could be gained from using this methodology as a base to study international disputes over shared watercourses and other shared natural resources to systematically seek out the core problems of such complicated conflicts from different perspectives.

8.17. Summary

This chapter discussed the findings from the study and evaluated the use of multi-framing as a framework to analyse the complex situation faced in the Egyptian-Ethiopian dispute over the Nile. Moreover, insights from the application of each of the individual analytical frames were discussed. Also, Section 8.11 has integrated the individual frames' findings to build a multi-pronged solution based on bringing all the strands together.

The researcher's observations of multi-framing in the context of this study were offered. Then it was followed by the participants' perceptions of the data interpretation and meaning-making processes. Multi-framing as an analytical method/approach was discussed to show how different frames and perspectives communicated different faces of complexity. Then, the key insights from the various analytical frames were explained through the analysis of perspectives and approaches at macro and micro levels.

The chapter then concluded that the approach used in this study could be an innovative methodology to study international disputes over shared watercourses and other shared natural resources.

Chapter 9
Conclusion and Recommendations

9.1. Introduction

The purpose of this research is to study the risks to Egypt's water supply due to the construction and operation of the GERD, particularly on Egyptian agriculture. This chapter first evaluates how effectively this purpose has been achieved by answering the research questions and objectives. Secondly, it discusses the research's different contributions. Thirdly, it highlights the limitations and future research of the study. Finally, it closes with a concluding statement.

9.2. Evaluating the research outcomes

Multi-framing is the process of investigating, viewing, and studying the same problem by using different frames/methods to cover different perspectives to reveal the problem's ambiguity, achieve a better understanding, and find some solutions (Mabin & Davies, 2004). This research sought to develop a multi-perspective and multi-framing methodology to understand the nature of risks to Egypt's water supply due to the GERD; identify the RCs; evaluate expected risks; understand how to control, alleviate them; and address the implications for Egypt. Particular attention was paid to the Egyptian agricultural sector. These perspectives included the historical, legal, risk, and TOC perspectives, while the frames included historical, legal, probability-impact matrix (PIM), decision trees, decision tables, and a suite of TOC frames. The study was intended to address identified research gaps by achieving the following research objectives:

- ➢ Develop a comprehensive, multi-perspective, multi-framing methodology to understand, investigate and evaluate the nature of the risks.
- ➢ Provide different stakeholders and decision makers with a better understanding and deep insights that highlight the uncertain nature of the current situation to support their decision-making process strategically and tactically by explaining different possible scenarios.
- ➢ Identify the root causes of the significant problems facing the Egyptian agricultural sector in particular, and the expected situation after the GERD in general.
- ➢ Address the current and expected implications for Egypt by offering different solutions that, when implemented, could help to overcome such problems.

The next section addresses how the four main research objectives were approached to understand how the study addressed the research questions and achieved its aims.

9.2.1. Research objective 1: A comprehensive, multi-perspective and multi-framing analysis to investigate, understand, and evaluate the nature of the studied risks (answering sub-questions number 1, 2, and 5)

It has been argued elsewhere that complex situations generally benefit from analysis using multiple frameworks and tools to incorporate various perspectives to provide a better investigation and understanding of the situation itself. This research has found that the risks associated with the Egyptian situation due to the GERD are complex. This research has therefore used a range of alternative perspectives and frames to provide complementary knowledge and insights into the Egyptian current situation and expected future due to the GERD.

The use of the multi-framing approach to gain deep insights into the agricultural sector in Egypt in this study is consistent with the literature. However, it must be emphasised that the researcher has chosen and conceived the different frames and their sequence in a way that provides the greatest benefit to the study itself. This is one of the characteristics of the multi-framing approach that authors can choose and conceive frames differently based on the study and the field itself.

While some authors have used metaphors to approach the multi-framing methodology (Bolman & Deal, 2017; Russo & Schoemaker, 1991), others have used systems-thinking-based methodologies along with metaphor in a mix-and-match manner (Mabin & Davies, 2004). In this study, the researcher used the concept of the multi-framing approach described by Davies and Mabin (2001b, 2004), which valued the nature of the frames and the way they work together through the context of the study itself.

The researcher chose to start with the historical and legal analytical frames. Both frames are descriptive, summarising and interpreting the literature concerning historical treaties and the legal situation of the dispute. It was deemed important to start the study with these two frames to shed light on the past in order to understand the current situation and provide a solid foundation for future-focused thinking. It was then followed by a number of prescriptive analytical frames that drew on different international experts alongside the Egyptian stakeholders at different levels, including the national, local and industry levels. The last suite of TOC frames, in particular, utilised information provided by government officials, politicians, farming sector workers, industry workers and other interested actors. TOC frames offered a significantly broad platform for understanding the sector to develop suitable recommendations.

The disparate views of participants highlighted the relevant issues from several perspectives creating complementary insights. These insights reflected some important issues related to the nature and root causes of the problem. Additionally, other characteristics showed general concerns that the challenges faced by the agricultural sector itself were extremely difficult, if not insurmountable, amid fears that it could collapse.

This complex situation led the researcher to choose different analytical frames. These multi-frames and perspectives together succeeded in achieving the research objectives and answering its questions. They also helped in achieving the second and third objectives of the study, as will be explained in the next sections.

9.2.2. Research objective 2: Highlight the chance/uncertain nature of the current situation to strategically and tactically support the decision-making process (answering sub-questions number 5 and 6)

This study aimed to provide the decision makers and stakeholders in Egypt with deep insights to assess the expected risks to Egypt's water supply due to the GERD. Additionally, this study explained the Egyptian decision alternatives based on different scenarios, while acting to improve them and find other alternatives.

This study mapped the expected likelihood (probabilities) and severity (impacts) of positive and negative risks, due to the construction of the GERD on Egypt, to classify and prioritise these risks. The study has made clear that the positive impacts of the GERD would not be significant and have almost no real positive impact on Egypt. On the other hand, the field study showed that it poses high-priority threats that were evaluated as almost certain to happen with catastrophic impact.

Since the quality of a decision relies on the quality of data, the researcher was keen to represent the voice of the two upstream countries in this study, alongside other international experts from different countries, to guide the decision-making process as well as represent the logic.

The decision analysis frames helped inform different decision makers and stakeholders to choose between various options and ultimately improve outcomes for everybody in Egypt. This analysis showed that two decisions were significantly beneficial to Egypt, namely, the "preparation" and "negotiation" decisions, while two were shown to be significantly costly, namely the "war" and "Do nothing" decisions. Moreover, allowing tensions to escalate leading inadvertently to war should also be avoided.

During this analysis, new decision alternatives emerged that would help improve the dispute's outcomes and provide a platform for better management. For instance, combining the preparation scenario and the negotiation scenario would be a good new decision alternative. The study excluded some decision alternative scenarios as well. For example, the participants ruled out the possibility of Ethiopia deciding to not fill the GERD's reservoir, except if a war was to occur.

9.2.3. Research objective 3: Identify root causes of the problem (answering sub-questions number 3 and 4)

The second objective of this study was to identify the main root causes of the problems facing the Egyptian agricultural sector in particular; the expected situation after the GERD in general; and then to address the implications for Egypt by offering solutions.

TOC analysis was used to explain how a significant number of symptoms (UDEs) that surfaced in the literature search and field study came from RCs that ultimately limit the achievement of the system's goals. With regard to these issues, the researcher used the GTs first to determine the main goals of the system. The researcher noted that almost none of the required CSFs and NCs to help attain the system's goals are currently being achieved. This tool has proved to be particularly useful where the process of identifying the goals prompted many participants to reflect on realistic goals for the Egyptian agricultural sector.

Two CRT models were created to capture cause-effect relationships between symptoms that surfaced during the field study and their RCs. The researcher found that the complexity of relationships between RCs and the UDEs of this situation was significantly underestimated by the majority of the participants when compared with those highlighted by the literature because they have not seen the whole picture.

This was the first time that TOC TP tools were used to work on the Egyptian-Ethiopian dispute or the agricultural sector in Egypt. The use of the TOC tools has enabled the extent of underrated complexity to be revealed. The researcher realised as well that the nature of the cause-effect relationships traversed issues at the national, international, and global levels. For example, the root cause of "Egypt suffers from water poverty" was at the national level. The root cause of "Ethiopia starts to fill the GERD reservoir" was at the international level, while the root cause of "climate change and global warming" was at the global level. The cause-effect relationships worked together to limit the outcomes for different stakeholders of the agricultural sector in Egypt, as was discussed in Chapter 7. Additionally, the presence of these critical RCs indicated that there are unresolved dilemmas.

9.2.4. Research objective 4: Address the implications for Egypt by offering different solutions that when implemented could help to overcome such problems (answering sub-questions number 7 and 8)

The ECs, FRTs, and PRTs addressed the implications for Egypt and offered different solutions that when implemented could help to overcome such problems. The ECs offered significant insights on win-win solutions, which were subjected to further analysis through FRTs, and PRTs.

Conceptualising the previous RCs as dilemmas helped the researcher to build a deeper understanding of the complexities of the current situation, in which ECs brought solutions and resolutions to the surface, by evaporating the more critical of these dilemmas. The main goals of the GTs were the main objective for some of the ECs, while the UDEs of the CRT and Cond. RT played as the conflicts and problems that each EC tried to solve.

The EC analysis suggested that the dilemmas due to the GERD in the long term, such as the environmental impacts, have not received the same deserved attention from stakeholders that those in the short term have. The researcher concludes that the consequences of the current situation in the short term are perceived to be excessively threatening and catastrophic, in comparison with the threats in the long term.

The researcher concludes that for effective resolution, there must be appropriate changes to Egyptian agricultural and economic policies to support the suggested ideas. However, change in policy needs high commitment, determination, will, and support of top leadership of the Egyptian government to support the agricultural sector so it can play its part in Egypt's survival and future prosperity.

This study shows how the current issues related to the Egyptian agricultural sector in particular, and the risks to Egypt's water supply, due to the GERD in general can be mitigated by incorporating the needed injections to ensure that all UDEs are turned into desirable effects. The FRT analyses served as a framework to change the future, in which different scenarios were mapped out.

The researcher observed that the problems of Egyptian water poverty and the agricultural sector issues already exist regardless of the GERD's future impacts. However, the GERD further exacerbates the problem. Moreover, the researcher noted that adopting new actions and policies is still required for effective management of the agricultural sector, and there is a need for the agricultural sector to become more resilient. However, the agricultural sector's response to change has been slow.

The PRT analysis succeeded in identifying the actions required for achieving Egypt's goal(s). It offered a comprehensive framework that acts as an action plan to overcome the expected obstacles. The proposed IOs were simple, practical, and most of them were cost-free, aside from finding new water resource alternatives.

Finally, the 5FS provided many specific recommendations to help with exploiting the constraint in our study, which was clearly identified as "water". In seeking to exploit the constraint, listing the reasons for water loss was a step towards reducing water losses. However, stopping these losses was insufficient to eliminate the water constraint. Actions aimed at subordinating other activities to ensure water is used most effectively have been detailed. However, while necessary, these actions will also be insufficient to stop the water supply from being the constraint.

At this point, however improved the constraint's performance is, it is still not enough to cover the required demands, especially given that Egypt suffers severe water scarcity. Therefore, the constraint would then need to be elevated by increasing its capacity, finding new water sources, and investing in better water infrastructure and agricultural methods. The case of connecting the Nile with the Congo River would tackle the water for Egypt and provides an option for Ethiopia to collaborate. Therefore, in such a case, FRT 2 would be applicable.

The 5FS offered different solutions, such as using some stored water from the AHD's reservoir or establishing and connecting water networks to other countries.

9.3. Significance of this research

The significance of this research lies in its originality and contributions. The utility of the multi-framing approach can be evaluated in terms of the theoretical and methodological advances made, in addition to its practical contributions. Each of these dimensions will be discussed in the following separate sections.

9.3.1. Originality

This case study of the potential risks expected from constructing the Ethiopian Dam on Egypt is new; no similar study has been conducted elsewhere on the same topic using the same perspectives, frameworks, tools, methodologies, and techniques for the analysis. All the outcomes of these frames have been combined to create the big picture. This study has focused on new perspectives, while studying the nature of the water supply shortage risks in Egypt due to the construction of the GERD. It also considered the impacts on the agricultural sector.

The originality lies in discovering the unexplored aspects of this Egyptian-Ethiopian dispute. The exploration and explanations offered are in themselves original works. The originality also includes the conceptualisation of the problem, the use of multiple frames to tackle it, and the original field study, which were all designed specifically to answer the research questions to produce new knowledge. This new knowledge has been unearthed and connected with already known data in a way that had not been done before. It is a significant addition to the accumulated knowledge within the management discipline in general and the multi-framing literature specifically.

9.3.2. Contributions

The major contributions of this study cover three different areas, the theoretical, methodological, and practical contribution, each of which will be discussed below.

9.3.2.1. Theoretical contribution

The researcher was surprised at the extent of the gap in the literature studying the risks regarding the Egyptian situation due to the GERD's construction and operation. The main weakness of the previous studies derived from not considering other relevant aspects and many other impacts that could affect the situation and outcomes. Most of these published discussions were one-dimensional analyses depending on only one or two perspectives at maximum. These analyses led to limited and single-track assessments of this conflict, which are inadequate as no one method can hope to model all of the pertinent aspects of complex situations.

This research has studied various risks of the GERD on Egypt's water supply in general, while particular attention was paid to the Egyptian agricultural sector. Different perspectives were achieved by using complementary analytical thinking frameworks and focusing on different aspects of the conflict. Using a multi-framing approach enabled more effective actions to be designed and offered a broader range of solutions to solve the problem. Choosing the multi-framing approach to study this case was in itself a theoretical contribution.

A significant theoretical contribution is also made via the creation of a new TOC TP tool "Conditional Reality Tree" (Cond. RT). The new tool is based on a conditional situation that is almost real, in contrast to typical CRTs, which usually only include the reality that exists. In the context of this study, the construction of the GERD is almost finished, while Ethiopia already has cut small portions of the Nile's water three times to test its turbines. It is not expected to be long before Ethiopia starts the complete filling process and operation of the GERD.

The researcher has developed a tool that uses the two logics of the TOC together at the same time. Cond. RT first applies the "necessity logic" before forming the tree itself. This logic is represented in "in order to form the CRT, the filling and the operation process of the GERD must be true." One action is necessary before the other can happen. The complete filling process must start first before the UDEs formed at this tree can happen. However, the condition, in this case, was not related to the logic applied during the constitution of the tree; it was the main condition assumed that underpins the shaping of the tree itself. Without assuming this condition, the researcher could not start forming the tree. However, to construct the tree, the tree itself follows the normal "sufficiency logic" as with any Reality Tree. It works out all the RCs and UDEs regarding the expected conditional reality due to the GERD by employing bottom-to-top sufficient-cause thinking.

A major advantage of using this new tool is that it combines the TOC's two logics consistently. In the broad sense, "logic" here refers to the schematic representation of reasoning procedures. One logic follows the general principle that underpins the articulation of the tree itself, while the other follows the forming principle that establishes the tree. This tool gives the opportunity to study scenarios that can be brought to reality in the short term based on a conditional situation that is almost real.

The invention of this tool was one of the main theoretical contributions in this study, benefiting all users of TOC TPs grappling with looming issues such as climate change/global warming and other imminent disasters such as population growth, international disputes, or wars.

9.3.2.2. Methodological contribution

One of the main methodological contributions in this study is made by contributing to the multi-framing body of knowledge and by extending it to the emergent, multi-framing approach of this study. This research is an addition to the literature of the integration of studying the expected risks regarding the Egyptian situation from different points of view.

The study has first reviewed the relevant literature to expose the inherent weakness in the literature relating to narrow analyses of these complicated risks. Then the research sought to understand the nature of these risks, identify the RCs, and create integrated risk analysis frameworks for decision makers. The findings advance theoretical knowledge and understanding by explaining the conceptual ambiguities about what constitutes the main problems that limit desirable outcomes of the agricultural sector in Egypt.

Another methodological contribution is the unique choice of frames included in this study. This innovative methodology itself is a key contribution of the thesis; no similar study has been conducted elsewhere on the same topic using the same perspectives, frameworks, tools, methodologies, and techniques for the analysis. These frames have been chosen to suit the situation and the researcher's expertise, in order to reveal deep insights. For example, TOC analytical frames have not previously been used to study this dispute and its associated risks. The study is the first of its kind in Egypt and worldwide to address such issues using the TOC TPs and 5FS.

Moreover, the sequential use of frames through the different frames incorporating increasing levels of complexity is in itself a methodological contribution. An example of moving between different frames in a certain sequential and progressive way is to move from the literature underpinning the first two frames to interviews and personal experiences from the other frames. An example of using tools in sequence within the one frame was the TOC TPs, in which its five different tools are used in a specific order. In this study, TOC TPs are using the change sequence framework to answer five fundamental questions in order. It starts with the GTs, then CRTs, ECs, FRTs, and finally PRTs.

This study makes a methodological contribution by contributing a novel methodology that will raise several implications for studying ongoing disputes over shared watercourses in general. Indeed, the analytical frames have provided a methodological framework for other similar disputes over shared watercourses. The proposed framework suggested by the researcher is recommended as one of the first frameworks that could be used to study disputes over shared watercourses in different countries.

The researcher believes that the choice of the unique perspectives and the different analytical frames included in this study, in such an order, taking into consideration the theoretical and practical goals of such types of disputes, fits the purpose well when studying international disputes over shared watercourses and other shared natural resources.

This novel methodology enabled the researcher to reframe issues such as surface symptoms of deeper RCs. It developed different frameworks that provided alternative perspectives and additional insights through the past, the present, and future situation of the dispute, which served both theoretical and practical value of the research across layers of various levels of government and the agricultural sector in Egypt.

9.3.2.3. Practical contribution

The study contributes to practice by offering a range of frameworks that can be embraced by different key stakeholders. This study of risk led to different findings, which would maximise the benefits for decision makers, stakeholders, and the Egyptian government. These findings are the practical contributions of this study. The stakeholders who will be impacted by these risks could include the Egyptian government, some industrial companies, which use Egyptian crops, industry executives, farmers, and the owners of agricultural lands.

In addition, the study has collated information via a wide variety of previous literature and stakeholders at different levels to provide a series of fresh and complementary perspectives on longstanding issues. This study clearly identified the goals and their CSFs and NCs that are required, for the studied sector and for Egypt in general regarding its water supply. In the context of this study, the main two goals of the Egyptian agricultural sector in general and in light of the expected risks to Egypt's water supply, due to the GERD were found to improve Egyptian agricultural performance and to ensure Egypt's survival. The CSFs and NCs in the GTs of this study covered a wide range of factors and conditions to achieve the success of the agricultural sector and Egyptian survival in general regarding the expected risks due to the GERD. Findings from this study have shown that neither CSFs nor NCs are currently achieved.

This study has succeeded in identifying the RCs of the problems related to the agricultural sector, as well as to Egypt's water supply in general. It has undertaken a deep investigation into the real causes and issues. It is expected that stakeholders would find the results of this study extremely useful to aid their understanding and to make progress if they were to decide to adopt the resulting recommendations.

Another practical contribution of this study is that it has defined and explained how increasingly precarious the real situation is, which would help in raising community awareness regarding Egyptian water poverty. It has offered specific plans to overcome the problem to meet both present and future water needs. It has also provided guidance on how to make the changes needed to improve outcomes. Potential solutions have been offered to bridge the gap between theory and practice that were previously missing.

This study of the risks facing Egypt, using these multiple frames, helped specifically in:

- New learning and explanations
    - It has suggested new techniques and methodologies to achieve efficient and effective water management practices in the use of water for agriculture through better farming practices, an increase in farmers' capabilities, and the use of appropriate irrigation systems.
    - It has proposed reducing water waste in the agricultural sector by using hoop houses and greenhouses; implementing different plans to make efficient use of the current water through water conservation techniques; changing the irrigation methods being used; maximising the use according to the required water quality; recycling and reusing waste water; and introducing water treatment plants.
    - It has clarified the importance of using effective and efficient irrigation systems, managing the agricultural process effectively, and rationalising water consumption for sustainability.
    - It has explained how the new agricultural practices will affect the agro-based industries, which will benefit stakeholders who would be impacted by these risks, such as industrial companies, which use Egyptian crops.
    - The study has suggested how Egyptians can use the available water for the greatest possible benefit.
    - The study has provided new ideas regarding new water resource alternatives that Egypt could use, such as: the idea of storing the rain in the Red Sea area by constructing non-rigid dams, the limited use of the groundwater at the Nubian Sandstone Aquifer System (NSAS), and/or establishing and connecting to water networks in other countries.

- Necessary actions
    - It has suggested the required changes to survive on reduced water, for instance by decreasing the growing of water-intensive crops and increasing the growth of water-conserving crops on existing lands.
    - This study has illustrated methods that could be used to better manage scarce water supplies, such as stopping water waste or limiting it to a minimum, suggesting approaches to control the water, and carefully prioritising the purposes for which water will be used among them.
    - It suggested different and new plans for the agricultural practices and crop maps in Egypt, which would provide significant benefits for the owners of the agricultural lands and farmers if adopted.

- It suggested the use of new advanced technologies for efficient and effective agricultural management practices, such as: IT, sustainability, and advanced thinking approaches.
- It suggested the use of new techniques and technologies to increase the efficiency and sufficiency of crops.
- The study has shown the need to change some inefficient agricultural laws that affect the agricultural sector badly, such as the land reform law in Egypt, issued in September 1952, which prohibited landowners from possessing more than 200 feddans of land.
- Moreover, it has pointed out that new laws and regulations are required to enforce and encourage conservative use of water, in addition to adequate representation and consultation.
- The study has shown different ways for effective governmental agricultural policy frameworks to strengthen externally and internally focused institutions.

➢ Expected benefits

- This study has investigated how to make effective use of water, considering it as a constraint, to squeeze every bit of capability out of it to exploit what is available before adding any additional resources.
- It found ways to effectively deal with competing water uses, found water resource alternatives to help in solving the problem with comparable prices, and suggests that certain international agreements could be useful in the agricultural sector, especially with Ethiopia.
- It proposed methods to employ efficient and effective land management through using updated land technologies (equipment, machinery), maximising crop yields, optimising crop choices
- The study has offered solutions to ensure sufficient crops in Egypt for the agro-industry sector after the expected decline of Egyptian crop production because of the GERD. For instance, importing the required crops from international markets would help to meet Egyptian industrial demands.
- This study has pointed out several solutions to the expected deficit in the production of Egyptian hydropower due to the GERD. It offered solutions such as buying affordable electricity from other countries.
- The study has suggested new methods to reduce the high rate of losses in Egyptian agricultural production through the storing, harvesting, milling, cold chain, or during the truck loading phase by using a Culture Value Chain.
- The study has shown different ways for effective governmental agricultural policy frameworks to strengthen externally and internally focused institutions.
- Stakeholders, who will be informed by this study's results, will benefit from adopting new agricultural plans based on the real situation.

9.4. Recommendations

In the context of this study, the two main goals of the Egyptian agricultural sector in general and the expected risks to Egypt's water supply due to the GERD are to improve Egyptian agricultural performance and to ensure Egypt's survival. Some other main CSFs were human well-being, a successful economy, and maintaining employment levels.

Building on the analysis and findings of this study, the recommendations that the researcher is offering have been divided into five categories based on the nature of the issues. These issues were related to water issues, the agricultural sector, national or governmental issues, new water resource alternatives, and finally international and foreign affairs.

9.4.1. Recommendations related to water issues

In light of the above goals, the researcher recommends that Egypt implements mandatory application of efficient and effective water management practices, to reduce water loss, including:

- Use effective and efficient irrigation systems.
- Line the water canals to prevent water leakage and improve the field irrigation process.
- Change the systems of irrigation canals and drains to be covered instead of remaining open to reduce evaporation rates and pollution.
- The reuse of treated agricultural drainage water for irrigation would help to control consumption.
- Moreover, Egypt should raise the efficiency of the current irrigation system, while changing the current flood irrigation system to a sprinkler, drip, or pivot system. The change in the irrigation system alone is expected to reduce at least 25% of the Egyptian agricultural water consumption. However, the Egyptian government should provide farmers with governmental financial support, or concessional bank loans, to assist and encourage them to change their irrigation systems.
- Egypt should use modern technologies, such as sensors in drinking taps, to conserve water, while reusing the treated wastewater from baths, showers, and hand basins. It should also use Supplemental Irrigation (SI) techniques where more than one water resource is used to irrigate the same area. This would help in saving the Nile's water in some areas and use desalinated water or rain instead to satisfy some partial needs.

9.4.2. Recommendations related to the agricultural sector

In light of the above goals, the researcher recommends managing agricultural processes effectively. The choice of appropriate crops should be made and applied through a national plan that includes the whole country. More drought-tolerant crops must be grown, while water-intensive crops must be avoided. Moreover, water-efficient desert plants should be grown to reduce water losses from transpiration.

Particular attention should be given to agricultural scientific research to introduce improved strains and seeds that require less water. Use the new strains of crops instead of the old ones. The use of modern mechanisation is one of the factors that would be effective to increase land productivity.

Egypt should use more environmentally friendly and sustainable agricultural practices to reduce water consumption, such as different types of fertilisers, and organic methods. Egypt should establish more associations to organise the irrigation process among farmers.

The use of vertical farming practices, wherever possible, could dramatically reduce water loss. This farming method uses 95% less water than traditional farming. This farming practice has the advantage of growing crops in vertically stacked layers, controlled-environment agriculture, and soilless farming techniques.

Post-harvest losses should be reduced. Those losses result from poor management of post-harvest systems, which include "on-farm losses, such as when the grain is threshed, winnowed, dried, inadequate harvesting time, climatic conditions, practices applied at harvest and handling, and challenges in marketing produce". Indeed, the research has identified that these losses are estimated to reach 15% to 50% depending on the type of crop. Reducing those losses by 50% will save 10% of the water used in the agricultural sector. The Egyptian crop losses are estimated to be higher than the Egyptian agricultural imports.

9.4.3. Recommendations related to national/governmental issues

In light of the above goals, the researcher recommends that the Egyptian government should prioritise the supply of water based on its purposes (domestic, civic, public, industrial, agricultural, business, or trade). Moreover, they should raise people's awareness about the problem of Egyptian water poverty, in order to encourage water conservation and the various techniques that allow for this. Media campaigns to raise awareness should be launched. These campaigns should reach out to all age groups (including farmers and normal citizens) and encourage water conservation as a national interest, especially aimed at long-standing practices and traditions (cultural, behaviours) which waste water.

The Egyptian government needs to display strong political will, commitment, vision, and good leadership to support the agricultural sector to eliminate corruption and bribery and ensure the right allocation and subsidies for the right people. The Egyptian government would need to take appropriate actions to effectively apply those proposed plans and policies. The researcher recommends that the government should prioritise decision-making mechanisms that support the changes in the economic and agricultural plans to ensure foreign and international investment.

The government should tackle rapid population growth that places a tremendous strain on resources and institutions in the country through different means. The government could take measures such as raising awareness regarding the problem, promoting a national family planning programme, and through government incentives.

The government should increase farmers' capabilities by providing good education in terms of schooling/tertiary, agricultural professional education, community services, infrastructure, housing, and professional services (extension services). It should provide them with training to improve their farming skills and to prepare them for the expected changes to Egyptian economic plans in different industries to ensure economic stability. The government needs to eliminate the black-market Mafia that controls the farmers and their intermediaries.

In addition, the researcher supports strong government engagement with different stakeholders, which is recognised in this study as a key to positive relationships and effective management of the expected risks. This strong engagement will help to overcome the resistance to change because of many social and cultural long-standing practices and traditions that affect the implementation of the required change in the agricultural sector. The dynamic nature of stakeholders reflects the differences in their stakes, interests, needs, and desires. The action plan needs effective and efficient national management to serve these different interests and to improve the overall outcomes.

Cooperation among different stakeholders, companies, and the Egyptian government is the key to success, through seeing mutually beneficial opportunities. For instance, the government should ensure the ordinary farmer is deeply aware of all aspects of water conservation, which could add value to their work and increase their share of water, which eventually would help to improve the economic welfare of the people and strengthen the overall relations in the community.

The researcher also recommends that the Egyptian government should meet the deficit in Egyptian crop production because of the GERD by importing crops from international markets or possibly growing crops elsewhere by renting lands in other countries. Moreover, it should meet the deficit in Egyptian hydropower production because of the GERD by using other renewable energy sources or new alternatives to generate electricity and buying cheap electricity from other countries.

9.4.4. Recommendations related to new water resource alternatives than the Nile River

Many new ideas regarding new water resource alternatives in addition to the Nile have been generated through the elaboration of this study's findings. These new water resource alternatives are as follows.

- Egypt is located at the end of the Nile journey. The Nile flows north into the Mediterranean Sea. Egypt can use more of the Nile's wasted water in the Mediterranean Sea by transporting 5 bcm via pipes, to avoid the loss of water by evaporation, to the Egyptian Western Desert to establish a new agricultural area.
- During the period that Ethiopia fills the GERD's reservoir, Egypt could use some of the water stored in the AHD's reservoir, to partially overcome water shortages. However, this water cannot cover the whole expected water shortage that Egypt would face. Egypt can use up to 90 bcm of the water stored in the AHD, which is the dam's live storage capacity. Exceeding this limit would damage the dam itself. However, Egypt cannot use all the water it has. This would be an extremely risky decision to make.
- Stored rainwater and floods could be useful in certain places, especially the Red Sea region. The possibility of constructing non-rigid dams to collect torrential downpours would be useful in such a region. However, Egypt has generally very low annual precipitation rates, which usually do not exceed 1 bcm. Moreover, rainwater is not available everywhere in Egypt, only in certain places, and cities.
- The use of the groundwater at the Nubian Sandstone Aquifer System (NSAS), which is considered the world's largest known fossil water aquifer

system, could contribute to Egypt's water supply. It extends under four countries including north-western Sudan, north-eastern Chad, south-eastern Libya, and most of Egypt. However, groundwater is a non-renewable water resource which should be used with great caution in the short term only and conserved for future generations. In addition, the location of the Aquifer itself makes it challenging to reclaim the surrounding lands or even to transport the water elsewhere because of high costs. In addition, it needs energy for pumping the water to the surface.

- Treated waste water and sewage recycling, including domestic sewage, industrial sewage, and agricultural runoff, could provide Egypt with a limited amount of water. However, this water needs appropriate treatment depending on waste water type and subsequent usage. For instance, agricultural runoff can be used to irrigate non-food crops, such as forests, woodlands, or crops that are used to produce goods for manufacturing, such as fibre for clothing, lavender, rapeseed, linseed, and hemp for essential oils, printing ink, and paper coatings.
- Seawater desalination is also an option to provide Egypt with water. However, it is beyond reasonable expenditure unless Egypt is provided with international loans. Additionally, desalination is an energy-intensive process. The cost would preclude its use for irrigation in the agricultural sector. It should only be used for domestic purposes.
- Connect the Congo River basin with the Nile basin. The Congo River is the second longest river in Africa after the Nile and the second largest river in the world by discharge volume after the Amazon. This river flows from its sources in the Congo to the Atlantic Ocean. Most of the river's water is wasted. A new cooperation through an international agreement would be required to connect the Congo River to one of the Nile's tributaries in Sudan. That would help in increasing the volume of the water in the Nile by 100 to 120 bcm/year and constructing a small dam to store water and generate electricity. In exchange, a capital investment could be made to support the Congo's economy by Egypt, or international entities such as the WB.
- The completion of the Jonglei Canal Project (JCP) is significantly important. JCP should divert the White Nile water through a canal to bypass the swampland to the East of El-Sudd to reduce water loss by transpiration and evaporation at the marshes and wetlands. This water loss was estimated by 50% of the Nile total flow passing by, about 14 bcm/year. The construction of this canal started in 1980 and had to stop in 1983 due to the outbreak of the Sudanese civil war. Therefore, the completion of this project should be urgently explored.
- Ethiopia has generous water resources. It would be helpful if the two countries, Egypt, and Ethiopia, could reach a bilateral agreement under which Ethiopia can sell some water to Egypt at a reasonable price. However, the cost of establishing the water network pipelines between the two countries would be slightly expensive at first.
- Sudan also has generous water resources, in comparison with Egypt. An Egyptian-Sudanese bilateral agreement would be required under which Sudan would allow Egypt to construct a dam on Sudanese lands to store water for the exclusive use of Egypt, in exchange for Egyptian investment in Sudanese infrastructure and the economy. As explained in Chapter 4, this

will not be the first time such dams have been constructed. There is a historical precedent in 1932, in which the Anglo-Egyptian administration in Sudan approved the construction of Jebel Aulia Dam on the White Nile to store water for the exclusive benefit of Egypt (Wassara, 2014).

9.4.5. Recommendations related to international and foreign affairs

The researcher advises that Egypt should reclaim its role as one of the most influential countries in Africa through maintaining its historical and cultural ties dating back thousands of years with its African neighbours. It also should improve and advance cooperative international relations with Ethiopia in particular, through effective externally focused institutions.

Based on this study, the researcher concludes that cooperation between the three countries, Egypt, Sudan, and Ethiopia, is the only way to end this dispute. A new trilateral agreement over the details of the process of filling and operating the GERD should take place. It should also be binding for all parties.

Creating shared goals, by establishing common projects, based on economic, socioeconomic and/or environmental interests between the two disputing countries would be extremely useful to provide a way of defusing the political tension related to the recent conflict. Agreeing and working towards common goals and interests would forge stronger relationships to enable successful cooperation, solving some of the key problems faced by the conflicted countries. Possibilities include:

- Constructing new road networks across the boundaries, developing an agricultural trilateral agreement, and/or establishing new plans to maintain food security.

- Creating a joint agricultural integration area in eastern Sudan. It is an extensive fertile area, which is estimated to be 8 to 12 feddans (bigger than Egypt’s total cultivated lands), Ethiopia could provide water and cheap electricity, and Egypt could provide professional experts, labourers, and money to fund the project.

- Establishing a free trade agreement, built on common economic interests, by creating a free trade area and regional integration zone in Ethiopia next to the lake, in Sudan, or the Halaib Triangle in Egypt. The Halaib Triangle is a disputed area of land located at the Egyptian-Sudanese border, over which both Egypt and Sudan have claimed sovereignty. This idea could end the dispute between the three countries over the GERD, as well as the Egyptian-Sudanese dispute over the Halaib Triangle.

There would be a huge opportunity for decision makers to benefit from the findings and recommendations of this research and the applied frameworks. These proposed plans and policies may guide their everyday political decision making to reap overall benefits for Egypt and its people.

9.5. Limitations

Price and Murnan (2004) define a research study’s limitations as influences that the researcher could not control and how they affect the research outcomes. This could include aspects of the research design that were unavoidable due to time, cost, or other practical considerations, that have constrained the research in some way. Therefore, this research has the following limitations.

Case selection
The first limitation is related to case selection. In the early stages of this research, it was decided that the focus of this study would be limited to a single case study to allow an in-depth investigation of the studied phenomenon. It was accepted that a single case study might limit the research findings but suited the topic best. This fits with exploring a phenomenon that allows the researcher to be totally focused on the topic under study rather than generate generalisable findings. Nonetheless, the study was still able to generalise the theoretical and methodological findings and the results of the qualitative analysis. These findings could be used on international disputes over shared watercourses and other shared natural resources as most of these disputes share the same nature.

Sample selection
The third limitation of this study is sample selection (participant selection). International interviews were conducted with participants from 9 different countries, 2 from Egypt, 2 from upstream countries, 5 from different European countries, and the last person was from another country. They were all international experts. It is worth mentioning that 2 of the participants have represented their countries in the ongoing Egyptian-Ethiopian negotiations. All the local interviews were conducted with Egyptians representing different categories, such as government representatives, industry representatives, Egyptian agricultural professionals, owners of agricultural lands, farmers, and academics who are specialists in risk management, water and irrigation management and agriculture.

All participants were chosen because they possess knowledge and information related to the agricultural sector and the likely impacts of the GERD. They were sourced through the researcher's professional and personal networks in this field. However, the results of this study have been affected by these choices, and outcomes might change if the participants changed. Great effort was made to ensure that all categories of participants were appropriately represented so that the outcomes would be as valid as possible.

Research into environmental impacts
The fourth limitation of this study is that the expected environmental impacts because of the GERD have not been completely studied because the participants have neglected them. The participants were more concerned with the short-term impacts rather than the long-term ones.

Research design choice
The final limitation is the choice of research design. Although this choice of research design in itself is considered to contribute theoretical and methodological advances, at the same time it is one of the research's limitations. It must be emphasised that the researcher has chosen and conceived the four different perspectives, the analytical frameworks and their sequence in a way that provides the greatest benefit to the study itself. Moreover, the multi-framing in the context of this study is characterised by the complementarity and differences of the various analytical frames. The multi-framing

makes a methodological contribution by contributing a novel methodology that will raise several implications for studying ongoing disputes over shared watercourses. However, research may be limited by the frames' choices and sequence. The results and findings might change if the choice and order of frames change. Thus, researchers should be open to the implications of choice and application of different frames in different orders.

9.6. Future research

Findings from this multi-perspective and multi-framing study of risks to Egypt's water supply have revealed many opportunities for further research. The first opportunity is the wider application of the multi-framing approach as an effective methodology to tackle this kind of situation. There is a need for the application of multi-framing for other key economic sectors in Egypt. This application would extend the study to a more practical utility of the approach as well as a better understanding of the Egyptian situation.

There is a need for further research that could provide more opportunities to consider the efficacy of the proposed novel methodology in studying international disputes over shared watercourses and other shared natural resources. This methodology could have huge implications for the studies of international water disputes. This will need to be tested in other cases and disputes. It is hoped that this methodology will have wider merit.

This research studied the dispute and the risks related to Egypt's water supply. There is a need for further research that could provide more insights and opportunities to study the dispute and risks from the Ethiopian and Sudanese points of view. The same analysis could also be conducted from Ethiopia's perspective to study how this dam could contribute to their economic growth, by selling hydropower, and reducing their electricity deficit.

There is a need for further research that could provide more insights into the nature of the situation by using the Game Theory to understand and analyse the strategic behaviours of both countries in such a complex situation. Game Theoretical approaches provide a means to study interactive decision-making and analyses strategies for dealing with competitive situations where the outcome of a player's choice of action depends critically on the actions of other players.

This was the first time that TOC frames were used to work on the Egyptian-Ethiopian dispute or even the agricultural sector in Egypt. In relation to the use of TOC in a wider range, more research opportunities are available through its application in other sectors in Egypt as well.

The findings of this study have indicated that there are several dilemmas at different levels facing Egypt due to the GERD. The exposition of these dilemmas separately and at the micro level, with more detail, might help provide more solutions. Moreover, the development of subsequent proposals of the currently proposed solutions in this study might help provide focus to wider continuous improvement initiatives. Additionally, more environmental studies are still required for the expected impacts because of the GERD on Egypt and the whole region.

Finally, this research has investigated undesirable matters related to the current situation. The purpose is not to put the Egyptian government in a negative light. Rather, this study has aimed to give an accurate and truthful portrayal of the situation and the root causes of these problems; evaluate expected risks; and understand how to control, alleviate, and mitigate them. It also has addressed the implications for Egypt, focusing, in particular, on Egypt's agricultural sector, in the hope that these findings might help Egyptian decision makers to better understand the nature of the studied risks and the whole situation. Additionally, the researcher hopes that these findings might also provoke debate and critical re-thinking about how they may be improved.

9.7. Concluding remarks/statement

I started my PhD journey in March 2019 at Victoria University of Wellington (VUW). In general, New Zealand has plentiful rainfall and a rich and fascinating nature. The environment offers great opportunities to come across different cultures and learn more about diversity. VUW provided me with all the resources I needed: a spacious office, a line-up of postgraduate workshops and all sorts of learning support. Above all things, I had great supervisors who supported me all the time in different aspects.

However, this journey was not easy, especially with the life I chose to have as a political and human rights activist and one of the Egyptian revolution leaders in 2011. Other circumstances, such as Covid-19's spread, the ensuing lockdowns, and travel restrictions which delayed my return to NZ after collecting my primary data, made the situation much more difficult and overwhelming. I succeeded in managing these complex challenges and eventually overcame them all.

I was certain that the key to succeeding was to approach the journey with patience, determination, and persistence. I knew I was the driver of my PhD journey, and I am the one responsible for my finishing time. I feel that the last few years have helped me grow. It has been a cocktail of joys and tears, which I truly appreciate.

I was passionate to explore how to manage the risks to Egypt due to the GERD by using a multi-perspective, and multi-framing approach due to several factors: my over 17 years of academic and practical experience in working on risk management techniques, accompanied by leading projects working on water resource management in Egypt, along with my reflections on my university learning experiences. I have always been curious about our contribution toward a better life for humans, especially in this case, where the risks would affect the lives of millions in Egypt. That was my reason behind choosing this topic.

One important thing that I learnt from my PhD is to see through complexities. My study has used different perspectives within a multi-framing approach to understand the nature of the risks to Egypt's water supply due to the GERD; identify the root causes; evaluate the expected risks; understand how to control, alleviate, and mitigate them; and address the implications for Egypt. Particular attention was paid to the Egyptian agricultural sector. These perspectives include the historical, legal, risk, and TOC perspectives, while the frames include the historical analytical frame, legal analytical frame, PIM frame, decision-making analytical frames, and a suite of TOC analytical frames. These perspectives and frames have offered complementary insights at both micro and macro levels. Moreover, my interactions with different stakeholders have helped me to understand the situation with all its complexity in a better way and learn how to tolerate ambiguity.

Moreover, as an Egyptian, I was very meticulous when working with the collected data to be sure that the stakeholders'/experts' voices are the only voices being portrayed in this research to ensure consistency in the narrative and avoid any possible bias. I also have included the participants' own words as comments in each chapter.

Indeed, data collection coincided with the several lockdown periods following the outbreak of Covid-19. This made it sometimes difficult to conduct interviews. However, it is worth mentioning that the researcher conducted a higher number of interviews than initially aimed for, within the planned fieldwork timeframe, despite this challenge.

Multi-framing helped to define the past and current situations and look forward to the future situation in Egypt. It helped to narrow the core problems that limit outcomes for stakeholders in Egypt as well as find solutions to overcome these problems. This study has achieved its overall purpose to provide stakeholders and decision makers with a better understanding of the Egyptian agricultural sector to enhance their decision-making processes. The study makes significant recommendations and offers contributions at all levels, theoretical, methodological, and practical.

Many theoretical contributions are made in this research. Using a multi-framing approach enabled more effective actions to be designed and offered a broader range of solutions to solve the problem. Choosing the multi-framing approach to study this case was in itself a theoretical contribution. A significant theoretical contribution is also made via the creation of a new TOC TP tool "Conditional Reality Tree" (Cond. RT). The researcher has developed a tool that is ideally suited to work on situations that represent imminent disasters.

Many main methodological contributions are made in this research such as: Contributing to the multi-framing body of knowledge by extending it to the emergent, multi-framing approach of this study; adding to the literature of the integration of studying the expected risks regarding the Egyptian situation from different points of view; and the unique choice of perspectives, frames and their specific sequential use that incorporate increasing levels of complexity.

Moreover, this study makes a major methodological contribution by contributing a novel methodology that will raise several implications for studying ongoing international disputes over shared watercourses from different aspects. As such, this thesis has a value not only to the Egyptian-Ethiopian dispute but also to any other dispute that could share the same characteristics. The proposed framework suggested by the researcher is recommended as one of the first frameworks that could be used to study disputes over shared watercourses in different countries.

The study contributes to practice by offering different practical suggestions, which would maximise the benefits for decision makers, stakeholders, and the Egyptian government. It has provided a series of fresh and complementary perspectives on longstanding issues. Another practical contribution of this study is that it has defined and explained how increasingly precarious the real situation is, which would help in raising community awareness regarding Egyptian water poverty. It has offered specific plans and necessary actions to overcome the problem to meet both present and future water needs. It has also provided guidance on how to make the changes needed to improve outcomes. Potential solutions have been offered to bridge the gap between theory and practice that were previously missing. It found ways to effectively deal with competing water uses and identified water resource alternatives to help in solving the problem.

Finally, my PhD experience has opened my eyes to explore complex things; focus my attention on things that matter; and think of possible solutions. I have become more confident that every problem has a solution; we just need to discover it.

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Appendix (A)

<u>HEC required documents</u>

Appendix (A) contains all the documents that related to this study and were required by HEC, which includes:

1) Letter invitation (recruitment email) for the international participants.
2) Oral invitation (phone invitation for the interview) for Egyptian participants.
3) Information sheet for participants.
4) Consent for interview.
5) Interview guide.
6) Interview questions.

Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam: A Multi-Perspective Study Using a Multi-Framing Approach

RECRUITMENT EMAIL

Dear (participant name),
My name is Abeer Youssef and I am a Doctoral student in School of Management at Victoria University of Wellington, New Zealand. I am contacting you to invite you to participate in my research project, which will underpin my thesis.

This project is studying the consequences and risks to Egypt's water supply due to the construction and operation of the Ethiopian Dam. Your participation will support this research by helping me to evaluate and assess the situation to understand the nature of the studied risks; identify the root causes; evaluate expected risks; and address the implications. That will lead to suggestions for an integrated solution for stakeholders and decision makers. This research has been approved by the Victoria University of Wellington Human Ethics Committee, Application reference number is 0000028185.

You have been invited to participate because of your great knowledge, information, and expertise related to this topic. You are in an ideal position to give me valuable first-hand information from your own perspective. I am simply trying to capture your thoughts and perspectives regarding this topic.

If you agree to take part, I will interview you through one of the communication technology applications (eg. Skype). I will ask you questions about the likely impact of the dam from your point of view. The interview will take about two hours. I will audio record the interview with your permission and write it up later. Your responses to the questions will be kept confidential. Each interview will be assigned a number code to help ensure that personal identifiers are not revealed during the analysis and write up of findings. You can choose to not answer any question or stop the interview at any time, without giving a reason. You can withdraw from the study by contacting me at any time within 48 hours of the interview. If you withdraw, the information you provided will be destroyed or returned to you.

Remember, this is completely voluntary. However, your participation will be a valuable addition to my research, and findings will lead to greater public understanding of this situation. If you are willing to participate, please suggest a day and time that suits you. If you have any questions please do not hesitate to ask me or my supervisor (contact details below).

Many thanks.
Abeer Youssef
Email: abeer.youssef@vuw.ac.nz
Phone: +20 1067-788-641

Supervisor: Professor Vicky Mabin, Victoria University of Wellington, Wellington, New Zealand +64 4 463 5140
vicky.mabin@vuw.ac.nz

Human Ethics Committee information
If you have any concerns about the ethical conduct of the research, you may contact the Victoria University HEC Convenor: Dr Judith Loveridge. Email hec@vuw.ac.nz or telephone +64-4-463 6028.

Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam: A Multi-Perspective Study Using a Multi-Framing Approach

ORAL INVITATION (through phone)

Hello (participant name),
My name is Abeer Youssef and I am a Doctoral student in School of Management at Victoria University of Wellington, New Zealand. I am calling to talk to you about participating in my research study, which is working towards my PhD thesis.

This project is studying the consequences and risks to Egypt's water supply due to the construction and operation of the Ethiopian Dam. Your participation will help me to evaluate and assess the situation: to understand the nature of the risks; identify the root causes; evaluate expected risks; and address the implications. I hope these will lead to suggestions for an integrated solution for stakeholders and decision makers.

You have been invited to participate because of your great knowledge, information, and expertise related to this topic. You are in an ideal position to give me valuable first-hand information from your own perspective. I am simply trying to capture your thoughts and perspectives regarding this topic.

If you agree to take part, I will interview you at your office or in a public place as per your preference. I will ask you questions about the likely impact of the dam from your point of view. The interview will take about two hours. I will audio record the interview with your permission and write it up later. Your responses to the questions will be kept confidential. Each interviewee will be assigned a number code to help ensure that personal identifiers are not revealed during the analysis and write up of findings. You can choose to not answer any question or stop the interview at any time, without giving a reason. You can withdraw from the study by contacting me at any time within 48 hours of the interview. If you withdraw, the information you provided will be destroyed or returned to you.

Remember, this is completely voluntary. However, your participation will be a valuable addition to my research, and findings will lead to greater public understanding of this situation. If you are willing to participate, we can go ahead and schedule a time for me to meet with you to give you more information. If you need more time to decide if you would like to participate, you may also call or email me with your decision.

Do you have any questions for me at this time?
If you have any more questions later about this study or if you need to contact me or my supervisor (Prof Mabin) about participation please do not hesitate. I may be reached on my email: abeer.youssef@vuw.ac.nz or my mobile number, which I am using now to communicate with you. My supervisor can be reached on vicky.mabin@vuw.ac.nz or +64-4-4635140

Thank you so much.

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam: A Multi-Perspective Study Using a Multi-Framing Approach

INFORMATION SHEET FOR PARTICIPANTS

You are invited to take part in this research. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to participate, thank you for considering this request.

Who am I?
My name is Abeer Youssef and I am a Doctoral student in School of Management at Victoria University of Wellington. This research project is working towards my thesis.

What is the aim of the project?
This project is studying the consequences and risks to Egypt's water supply due to the construction and operation of the Ethiopian Dam. Your participation will support this research by evaluate and assess the situation to understand the nature of the studied risks; identify the root causes; evaluate expected risks; understand how to control, alleviate, forecast them; and address the implications. That will lead to suggestions for an integrated solution for stakeholders and decision makers. This research has been approved by the Victoria University of Wellington Human Ethics Committee. Application reference number is 0000028185.

How can you help?
You have been invited to participate because of your great knowledge, information, and expertise related to the topic. If you agree to take part, I will interview you at your office or in a public place as your preference. I will ask you questions about the likely impact of the dam from your point of view. The interview will take about two hours. I will audio record the interview with your permission and write it up later. You can choose to not answer any question or stop the interview at any time, without giving a reason. You can withdraw from the study by contacting me at any time within 48 hours of the interview. If you withdraw, the information you provided will be destroyed or returned to you.

What will happen to the information you give?
This research is confidential. This means that the researcher named below will be aware of your identity but the research data will be combined and your identity will not be revealed in any reports, presentations, or public documentation.

Only I, my supervisors, and the transcriber (who will be required to sign a confidentiality agreement) will read the notes or transcript of the interview. The interview transcripts, summaries and any recordings will be kept securely and destroyed on or before 01/07/2030.

In addition, access to participants' audio recordings will be restricted to the investigator and transcriber.

What will the project produce?
The information from my research will be used in my PhD thesis, academic publications, presented to conferences, and professional reports.

If you accept this invitation, what are your rights as a research participant?
You do not have to accept this invitation if you do not want to. If you do decide to participate, you have the right to:

- Choose not to answer any question;
- Choose not to have the interview recorded;
- Choose to record the interview but have the right to ask no one can hear it except the researcher and transcriber (who will be required to sign a confidentiality agreement);
- Ask for the recorder to be turned off at any time during the interview;
- Withdraw from the study within 48 hours of the interview;
- Ask any questions about the study at any time;
- Receive a written summary of your interview;
- Be able to read the final report of this research by indicating your request on the consent form or emailing the researcher to request a copy.

If you have any questions or problems, who can you contact?
If you have any questions, either now or in the future, please feel free to contact:

Student:
Name: Abeer Youssef
Abeer.Youssef@vuw.ac.nz

Supervisor:
Name: Prof. Vicky Mabin
School: Management
Phone: +64 4463-5140
Vicky.Mabin@vuw.ac.nz

Human Ethics Committee information
If you have any concerns about the ethical conduct of the research, you may contact the Victoria University HEC Convenor: Dr Judith Loveridge.
Email hec@vuw.ac.nz or telephone +64-4-463 6028.

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam: A Multi-Perspective Study Using a Multi-Framing Approach

CONSENT TO INTERVIEW

This consent form will be held for a maximum of ten years.

Researcher: Abeer Youssef, School of Management, Victoria University of Wellington.

- ☐ I have read the Information Sheet and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.
- ☐ I agree to take part in an audio-recorded interview.

understand that:

- ☐ I may withdraw from this study at any point within 48 hours of the interview, and any information that I have provided will be returned to me or destroyed.
- ☐ The identifiable information I have provided will be destroyed on 01/07/2030.
- ☐ Any information I provide will be kept confidential to the researcher, the supervisors and the transcriber.
- ☐ I understand that the findings may be used for a PhD dissertation, academic publications, presented to conferences, and professional reports
- ☐ I understand that the recordings will be kept confidential to the researcher and the transcriber.
- ☐ My name will not be used in reports and utmost care will be taken not to disclose any information that would identify me.
- ☐ I would like to receive a copy of the final report and have added my email address below. Yes ☐ No ☐

Name of participant: ________________________________

Date: ______________

Contact details: ________________________________

Signature of participant: ________________________________

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Management of Risks to Egypt's Water Supply due to the Grand Ethiopian Renaissance Dam: A Multi-Perspective Study Using a Multi-Framing Approach

Interview guide

Attached is an interview guide listing the full set of possible questions I intend to ask. Participants will be asked subsets of these questions as explained in the following table.

Question number	Questions type	Level of targeted Interviewees
1 & 2	Personal background	All participants
3, 4, 5 & 6	Risk analysis frames (Probability & impact matrix)	National, government, academics & those in high positions of agriculture sector
7 & 8	Scenario analysis frames (decision tree & game theory table)	National, government, academics & those in high positions of agriculture sector
From 9 to 21	TOC (TP tools)	Other sector representatives & individuals
22, 23, 24, 25 & 26	TOC (5FS)	Other sector representatives & individuals

Interview questions
International interviews

Personal background
Interviewee name:
Code:

1) What is your job title?

2) How many years of experience do you have in your career/sector?

Risk analysis Frames (Probability & impact matrix) questions

3) Regarding the effect of the Ethiopian dam, could you please rate the likelihood of the occurrence of the negative risks on the following scale?
10%   30%   50%   70%   90%

4) Could you please rate the impact of these risks on the following scale?
5% (Very low)   10% (Low)   20% (Moderate)   40% (High)   80% (Very high)

5) Regarding the effect of the Ethiopian dam, could you please rate the likelihood of the occurrence of the positive risks (opportunities) on the following scale?
10%   30%   50%   70%   90%

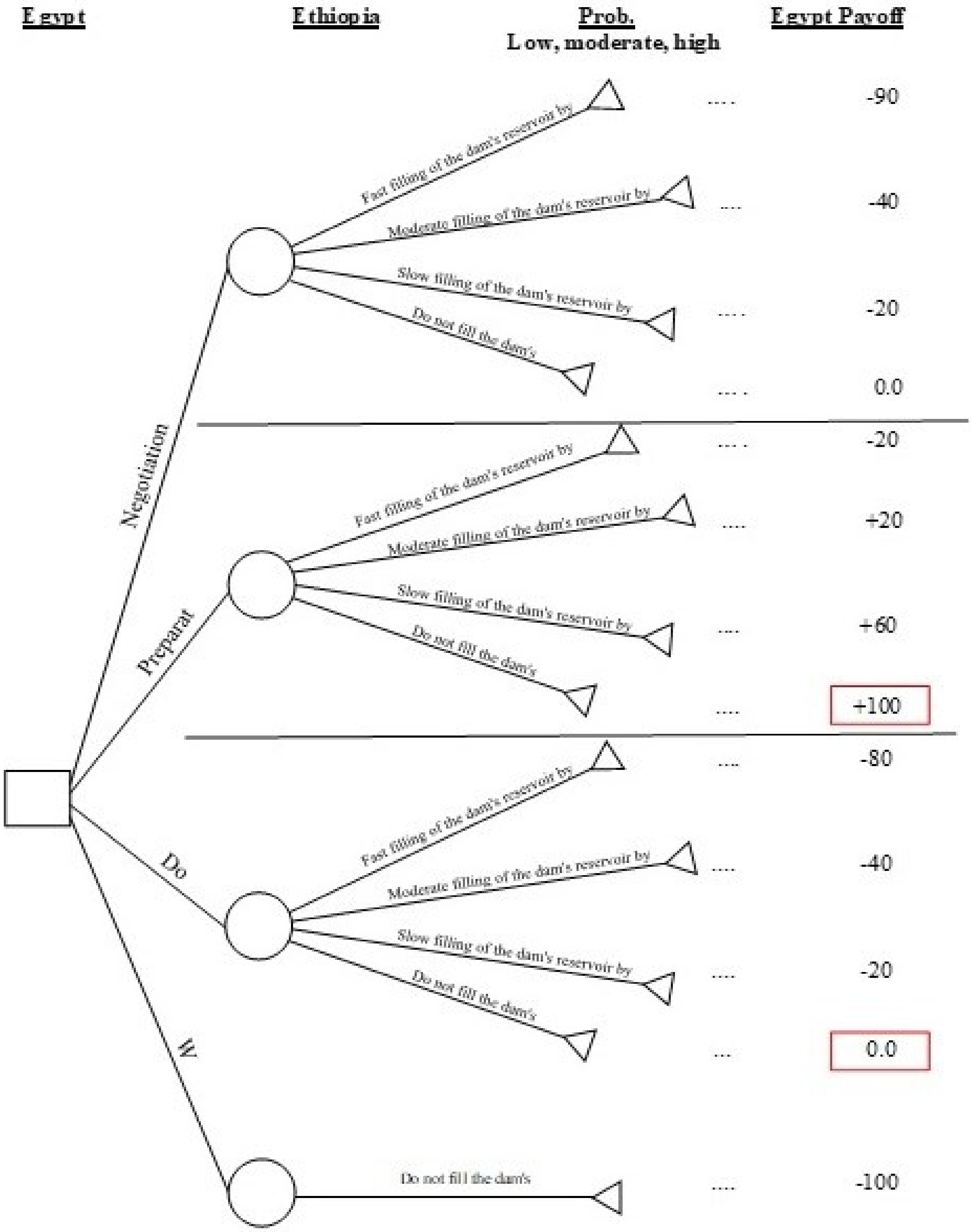
6) Could you please rate the impact of these opportunities on the following scale?
5% (Very low)   10% (Low)   20% (Moderate)   40% (High)   80% (Very high)

Decision analysis frames

7) For the following scenario options (decision table), what do you think the outcomes will be for Egypt and Ethiopia? Please use values between 0 and 100.

	Ethiopia decision	
Egypt decision	Engage in negotiation & fill the dam reservoir at a moderate rate	Refuse to negotiate & fill the dam reservoir at a fast rate
Prepare		
Do nothing		
Negotiate		
Start a war		

8) For the decision tree below, please check the payoffs suggested for different scenarios. Then using the anchor points +100 and 0 for payoffs as shown, please adjust the other values to represent your view. Please also indicate the likely probabilities.



National interviews

Personal background
Interviewee name:
Code:

1) What is your job title?

2) How many years of experience do you have in your career/sector?

TOC (5 FS) & TP frames questions

3) Could you please tell me your role and briefly describe your experience in this role?

Goal Tree (GT)

4) Thinking about the agriculture sector in Egypt, do you think any changes are needed?
5) What would you say is the goal(s) of the agriculture sector and the critical success factors necessary for achieving that goal(s)?
6) What would you say is the goal(s) of your own work and the critical success factors necessary for achieving that goal(s)?
7) What are the necessary conditions required to satisfy the important/critical success factors you just identified?
    a. Which (if any) of these necessary conditions are not being met now?
    b. What about when the dam starts operating?

Current Reality Tree (CRT)

8) Are there specific problems (undesirable issues) you have experienced within your sector/work?
9) Why do you identify these problems as being undesirable or bad?
    a. What do you feel really causes these problems?
    b. How do these problems (undesirable issues) affect the sector's ability to achieve its goals?
    c. Does the sector continue to put up with the problem/undesirable issues?

10) In the condition of Egypt's water supply shortage because of the GERD, are you expecting specific problems (undesirable issues) you will encounter within your sector/work?
11) Why do you identify these issue(s) as being undesirable or bad in this certain condition?
    a. What do you feel really will cause these problems or undesirable issues?
    b. How will the expected problems or undesirable issues affect the sector's ability to achieve its goals?
    c. Will the sector continue to put up with the problem/undesirable issues?

Evaporating Cloud (EC)

12) Do you expect to experience any conflicts or dilemmas because of these problems or undesirable issues? (Now and in the future once GERD starts operating)
    a. Please describe the conflict or the dilemma.
    b. What suggestions would you recommend helping alleviate this future problem or eliminate the conflict?

Future Reality Tree (FRT)

13) If your recommended solution were implemented, what benefits would you expect to see as a result of these actions?
14) Do you foresee any negative side effects if this solution was in place?

Prerequisite Tree (PRT)

15) What obstacles do you think are likely to be faced, when trying to implement the proposed solution?
    a. In your opinion, how would you overcome these obstacles?
    b. Have you developed (or do you know of) any strategies to overcome these obstacles?

TOC five focusing steps (5 FS)

16) Going back to the bigger picture, what is the biggest constraint you will face in your sector?
17) How can we use the existing (amount/level) of that resource (the constraint, e.g., water) in a most effective way, more than they are used right now?
18) Are there any other resource(s) that could be used to help manage the constraint most effectively?
19) How can we get more of the constraint's resources (e.g., water)?
20) Do you have any other comment you want to add?

Appendix (B)

Evaporating Clouds 2-13: Entities, key assumptions, Injections and UDEs

EC (2)	
In order to have "A", Egypt must do/have "B" & "C"	In order to have a sustainable water supply to meet the Egyptian requirement needs (A), Egypt must maintain an adequate volume of water (B) & reasonable costs for the water supply (C).
BD	In order to maintain an adequate volume of water for Egypt (B), Egypt must utilize different water sources than the Nile (D).
CD'	In order to have reasonable costs for water supply (C), Egypt must rely on the Nile only (D').
Assumptions	BD1- The Nile water is insufficient on its own to supply future needs (especially in the case of the GERD). CD'1- The Nile is the cheapest source for water supply.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt can maintain an adequate volume of water (B) & rely on the Nile only (D') by: BD1- Sign an international agreement with Ethiopia. BD2- Reduce water consumption.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt can have reasonable costs for the water supply (C) & utilize different water sources than the Nile (D) by: CD'1- Get funds through international entities.
The UDE that needed to be avoided	UDE1: Egypt already suffers from water poverty.

EC (3)	
In order to have "A", Egypt must do/have "B" & "C"	In order to display strong political will, support, vision, and leaders to support the agricultural sector by the Egyptian government (A), Egypt must reduce corruption and bribery (B) & minimise disruption to Egyptian performance (C).
BD	In order to reduce corruption and bribery (B), Egypt must implement an effective/efficient governmental institutional structure and laws (D).
CD'	In order to minimise disruption to Egyptian performance (C), Egypt must stay with the same governmental institutional structure and laws (D').

EC (3)	
Assumptions	BD1- Laws are not properly enforced by the current governmental institutional structure and laws. BD2- Laws are not equally applied to everybody because of governmental corruption. BD3- Corruption here involves corruption related to politicians, government officials, and public servants. CD'1- Changing the governmental institutional structure and laws disrupts Egyptian performance.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must reduce corruption and bribery (B) & stay with the same governmental institutional structure and laws (D') by: BD1- Improve the education facilities to increase public awareness about corruption & bribery and their serious effects on the whole country.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt can minimise disruption to Egyptian performance (C) & implement effective/efficient governmental institutional structure and laws (D) by: CD'1- Make the required changes in the governmental institutional structure and laws gradually. CD'2- Engage the small stakeholders, so there will be no resistance to change.
The UDE that needed to be avoided	UDE37: Egypt experiences widespread long-standing corruption and bribery. UDE27: Egypt has an ineffective governmental institutional framework and structure. UDE38: Laws are not enforced in Egypt.

EC (4)	
In order to have "A", Egypt must do/have "B" & "C"	In order to improve the Egyptian agricultural sector (A), Egypt must maximise the benefits of the use of the land/water unit in the long term (B) & avoid harming the agricultural and agro-industry sectors' performance in the short term (C).
BD	In order to maximise the benefits of the use of the land/water unit (B), Egypt must institute new/better agricultural management plans (new crops, new irrigation methods...) (D).
CD'	In order to avoid harming the agricultural and agro-industry sectors' performance in the short term (C), Egypt must use the same agricultural management plans (D').

EC (4)	
Assumptions	BD1- The use of the current agricultural management plans is wasting huge amounts of water. CD'1- To maintain the current agriculture and agro-industries performance, Egypt needs to keep growing the same current crops, on which the current agro-industries depend.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must maximise the benefits of the use of the land/water unit (B) & use the same agricultural management plans (D') by: BD1- Eliminate the fragmentation of the landholding problem, which reduces the productivity of both land and water.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt avoids harming the agricultural and agro-industry sectors' performance in the short term (C) & institutes new/better agricultural management plans (D) by: CD'1- Import the required quantities of crops for agro-industries. CD'2- Make a slow and gradual shift between the old plans and the new ones.
The UDE that needed to be avoided	UDE49: Egypt uses ineffective/inefficient agricultural management practices.

EC (5)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maintain the Egyptian electricity production (A), Egypt must ensure the success of the Egyptian electricity management (B) & ensure the efficiency of the electricity generation system (C).
BD	In order to ensure the success of the Egyptian electricity management (B), Egypt must maintain the share of hydroelectricity in total Egyptian electricity production (D).
CD'	In order to ensure the efficiency of the electricity generation system (C), Egypt must reduce the share of hydroelectricity in total Egyptian electricity production (D').
Assumptions	BD1- Hydropower generation in Egypt is still more environmentally friendly and cheaper in comparison with traditional fossil fuel-based power plants. CD'1- The efficiency of the Egyptian electricity generation system depends on utilising other resources than hydropower. CD'2- Egyptian electricity production is less expensive in general.

EC (5)	
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must ensure the success of the Egyptian electricity management (B) & reduce the share of hydroelectricity in total Egyptian electricity production (D') by: BD1- Find new alternatives to generate electricity. BD2- Buy electricity from other countries.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt ensures the efficiency of the electricity generation system (C) & maintains the share of hydroelectricity in total Egyptian electricity production (D) by: CD'1- Adopt new plans gradually. CD'2- Use other renewable energy sources to generate electricity to be consumed or sold to other countries.
The UDE that needed to be avoided	UDE19: The efficiency of the hydropower generation share is not ensured. UDE20: The Egyptian electricity production is insufficient.

EC (6)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maintain the employment rate in the agricultural and agro-industries sectors (A), Egypt must avoid increasing the unemployment rate (B) & ensure sufficient trained workers for the new jobs (C).
BD	In order to avoid increasing the unemployment rate (B), Egypt must continue using the same plans in the two sectors (D).
CD'	In order to ensure sufficient trained workers for the new jobs (C), Egypt must use different plans in the two sectors (D').
Assumptions	BD1- The production of the Egyptian crops must be maintained to continue using the same plans in the two sectors. CD'1- Ensure low cost in training while using the same workers. CD'2- The production of the materials/crops (by the agricultural sector) is not enough for the agro-industry sector.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must avoid increasing the unemployment rate (B) & use different plans in the two sectors (D') by: BD1- Reallocate the workers/labourers to other suitable positions. BD2- Open new markets that could be suitable for these workers' experience.

EC (6)	
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must ensure sufficient trained workers for the new jobs (C) & continue using the same plans in the two sectors (D) by: CD'1- Import the required raw materials/crops so the workers continue working in the same fields/factories, while offering training that can gradually change their set of skills.
The UDE that needed to be avoided	UDE76: The unemployment rate increases.

EC (7)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maintain the viability of the agro-industry system (A), Egypt must maintain the continuity of agro-industry production in short term (B) & ensure the long-term viability of the agro-industry sector (C).
BD	In order to maintain the continuity of agro-industry production in short term (B), Egypt must keep the current Egyptian crops (D).
CD'	In order to ensure the long-term viability of the agro-industry sector (C), Egypt must change the crop production (D')
Assumptions	BD1- Maintaining the continuity of agro-industry production depends on continue growing the same crops. CD'1- The new crops need less water.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must maintain the continuity of agro-industry production in short term (B) & change the crop production (D') by: BD1- Import the required raw materials/crops so the workers continue working in the same fields/factories. BD2- Grow crops somewhere out of Egypt by renting lands in other countries.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must ensure the long-term viability of the agro-industry sector (C) & keep the current Egyptian crops (D) by: CD'1- Apply new policies to make a gradual change to the sector.
The UDE that needed to be avoided	UDE23: The agro-industry is seriously impacted.

EC (8)	
In order to have "A", Egypt must do/have "B" & "C"	In order to minimise the risks and effects of the GERD construction on Egypt (A), Egypt must avoid Egyptian widespread organisational disruption (B) & avoid Egyptian economic failure (C).

EC (8)	
BD	In order to avoid Egyptian widespread organisational disruption (B), Egypt must have no system change for the affected sectors (D).
CD'	In order to avoid Egyptian economic failure (C), Egypt must have new plans for the affected sectors (D').
Assumptions	BD1- New plans for the affected sectors will disrupt the Egyptian organisational performance. BD2- The Egyptian performance disruption would happen because of the GERD. CD'1- The Egyptian economic failure would happen because of the GERD.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must avoid Egyptian governmental performance disruption (B) & have new plans for the affected sectors (D') by: BD1- Apply the new plans gradually to avoid the Egyptian performance disruption. BD2- Provide the workers with adequate training to avoid the Egyptian performance disruption.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must avoid Egyptian economic failure (C) & have no system change for the affected sectors (D) by: CD'1- Open new markets for other sectors to avoid the Egyptian economic failure CD'2- Encourage foreign investments in new sectors.
The UDE that needed to be avoided	UDE75: The negative impact on the Egyptian economy is massive.

EC (9)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maintain the Egyptian economic performance (A), Egypt must maintain the continuity of economic activities on the short term (B) & ensure the resilience of the Egyptian economy on the long term (C).
BD	In order to maintain the continuity of economic activities on the short term (B), Egypt must have the same amount of the Nile water (D).
CD'	In order to ensure the resilience of the Egyptian economy on the long term (C), Egypt must reduce the water obtained from the Nile (D').
Assumptions	BD1- The same amount of water maintains the production of the crops needed for the agricultural and agro- agricultural sectors. CD'1- Economic activities depend on water. CD'2- The current amount of the Nile water is not enough to help the expansion in economic activities.

EC (9)	
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must maintain the continuity of economic activities on the short term (B) & reduce the water obtained from the Nile (D') by: BD1- Depend on other water resources alternatives to maintain the continuity of economic activities on the short term. BD2- Change the used technologies and techniques to decrease water consumption and reduce waste.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must ensure the resilience of the Egyptian economy on the long term (C) & have the same amount of the Nile water (D) by: CD'1- Apply new economic activities to maximise the Egyptian economic performance. CD'2- Adopt a new Egyptian vision to change the Egyptian behaviours to reduce water consumption so it could be stored for later use.
The UDE that needed to be avoided	UDE79: Poverty rate increases.

EC (10)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maintain public health (A), Egypt must have the same water quality (B) & maintain the Egyptian-Ethiopian relationship (C).
BD	In order to have the same water quality (B), Egypt must stop Ethiopia from filling the GERD (D).
CD'	In order to maintain the Egyptian-Ethiopian relationship (C), Egypt accepts Ethiopia continuing to fill the GERD (D').
Assumptions	BD1- Filling the dam affects the water quality. BD2- The extra cost that would be paid by Egypt to sell electricity to Ethiopia is much bearable than the decrease in the water amount reaching Egypt. CD'1- Avoiding the war by accepting the Ethiopian decision in continuing filling the dam would maintain the Egyptian public health. CD'2- Ethiopia constructs the GERD for electricity.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must have the same water quality (B) & Egypt accepts Ethiopia continuing filling the GERD (D') by: BD1- Ethiopia fills the reservoir over a long period of time. BD2- Ethiopia pays for the treatment required for the Egyptian water.

EC (10)	
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must maintain the Egyptian-Ethiopian relationship (C) & Egypt must stop Ethiopia from filling the GERD (D) by: CD'1- Egypt compensates Ethiopia for the losses incurred by not operating the GERD. CD'2- Egypt sells cheap electricity to Ethiopia.
The UDE that needed to be avoided	UDE81: Public health deteriorates.

EC (11)	
In order to have "A", Egypt must do/have "B" & "C"	In order to control social/civil unrest and reduce crime rates (A), Egypt must ensure social stability (B) & ensure economic stability (C).
BD	In order to ensure social stability (B), Egypt must maintain the same sectors and numbers of jobs (D).
CD'	In order to ensure economic stability (C), Egypt must make a change in the sectors and number of jobs (D').
Assumptions	BD1- The new economic plans are required different workers' qualifications. CD'1- Using new economic plans is required to avoid the increase in the unemployment rate.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must ensure social stability (B) & make a change in the sectors and numbers of jobs (D') by: BD1- Provide suitable training to workers to prepare them for the new jobs. BD2- Adopt resilient new economic plans to make a change gradually on the long-time term.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must ensure economic stability (C) & maintain the same sectors and numbers of jobs (D) by: CD'1- Open new markets to ensure the availability of enough jobs. CD'2- Import required materials/crops to maintain the current jobs.
The UDE that needed to be avoided	UDE78: The crime rate increases UDE80: Instances of civil unrest with violence steadily increase.

EC (12)	
In order to have "A", Egypt must do/have "B" & "C"	In order to maximise the well-being of Egyptians (A), Egypt must avoid Egyptian financial bankruptcy (B) & maintain the stability of the government's managerial performance (C).

EC (12)	
BD	In order to avoid Egyptian financial bankruptcy (B), Egypt must apply new management and decision-making techniques (D).
CD'	In order to maintain the stability of the government's managerial performance (C), Egypt must continue using the current management and decision-making techniques (D').
Assumptions	BD1- The current Egyptian management and decision-making techniques are not efficient. BD2- Borrowing money, loans, and selling some Egyptian assets could be only considered as a short-term solution. CD' 1- New management and decision-making techniques will disrupt the government's managerial performance.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must avoid Egyptian financial bankruptcy (B) & continue using the current management and decision-making techniques (D') by: BD1- Take out an international loan to avoid the Egyptian system's financial bankruptcy. BD2- Sell some of the Egyptian assets.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must maintain the stability of the government's managerial performance (C) & apply new management and decision-making techniques (D) by: CD'1- Apply new plans gradually to avoid undermining the Egyptian government's performance. CD'2- Engage citizens in the political process and raise awareness using the media to avoid disturbing the managerial performance of the Egyptian government.
The UDE that needed to be avoided	UDE82: Egyptian welfare is seriously impacted.

EC (13)	
In order to have "A", Egypt must do/have "B" & "C"	In order to ensure Egypt's survival (A), Egypt must maintain Egypt's economic performance and welfare (B) & maintain good international relationships with the neighbouring countries (C).
BD	In order to maintain Egypt's economic performance and welfare (B), Egypt must maintain the Egyptian share of the Nile water (D).
CD'	In order to maintain good international relationships with the neighbouring countries (C), Egypt must reduce the Egyptian water share from the Nile (D').
Assumptions	BD1- The same amount of the Nile's water is required for economic activities.

EC (13)	
	CD'1- Accepting the Ethiopian terms would maintain both countries' relations. CD'2- Maintaining a good international relationship is important to Egypt.
Injections B & D' (Ways of achieving B while doing D') Breaking the BD arrow	Egypt must maintain Egypt's economic performance and welfare (B) & reduce the Egyptian water share from the Nile (D') by: BD1- Buy water from other countries. BD2- Find additional water sources (e.g., Nubian aquifer). BD3 - Become more efficient in using water.
Injections C & D (Ways of achieving C while doing D) Breaking the CD' arrow	Egypt must maintain good international relationships with the neighbouring countries (C) & maintain the Egyptian share of the Nile water (D) by: CD'1- Neighbouring countries recognise Egypt's historical rights and sign an international agreement with the other countries regarding how to manage the Nile as a shared watercourse. CD'2- Egypt pays for the damage that will occur to the other countries.
The UDE that needed to be avoided	UDE83: Egypt's chance of survival is impossible.