A Negotiation Support System for Resolution of Disputes over International Water Resources

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A Negotiation Support System for Resolution of Disputes over International Water Resources

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to the memory of my father

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Abstract

This work is concerned with the development of a methodology and tools for aiding negotiations over shared international water resources. Experience shows that under conditions of water scarcity, often exacerbated by inefficient management of water resources (such as under-pricing and over-pumping), the result is real or at least perceived shortage of water and a drive to obtain as much as possible from disputed water sources. This frames the conditions under which international negotiations over shared water resources is conducted in many parts of the world. On the other hand, it has been shown that concepts of water markets have a potential to increase the efficiency of water utilization (*Shechter, 1994; Becker & Zeitouni, 1998; Fisher et al., 2002)*, thereby reducing the stress and the losses due to scarcity. In the context of international negotiations over shared resources, the market approach aims at determining an efficient allocation of water resources based on a system of voluntary trade in water, which brings potentially large benefits to all parties involved.

We propose a collaborative Negotiation Support System (NSS) as a dispute resolution framework, to assist the parties in searching for feasible and satisfying solutions to management of the shared resource. It uses features of a water market system that help in determining an optimal allocation of an international water resource, driven by objectives and subject to constraints imposed by the negotiators: hydrological, physical, political and economic. A central component of the NSS is therefore the Water Allocation System WAS (*Fisher et al., 2002*) that allocates water while maximizing total social net benefit from water supply to all consumers in a defined region.

The NSS is designed for support of bilateral negotiations. It is based on symmetry and provides an identical set of tools to both parties. The negotiation is viewed as consisting of

two main processes: individual decision-making and joint problem solving. The individual decision support is designed to assist each party in structuring its systems of preferences related to the water allocation problem. Each party establishes its utility for negotiated alternatives, using the AHP algorithm (*Saaty, 1980)* to weigh and combine its various objectives, with the economic objective being just one of them, into a single utility figure. Joint problem solving is modeled as an interaction, supported by tools from game theory, in which the parties have the opportunity to design and select efficient and jointly preferred solutions. The negotiation process is modeled as an alternating sequence of individual and joint activities, in which the parties manipulate the set of alternative solutions, aimed at enlarging the negotiation space by creating and proposing new alternatives, and narrowing it by removing non-efficient ones. The two processes are repeated in a series of iterations, which terminate when a stable negotiation solution is reached (or the negotiations fail and are broken off).

The WAS model provides assistance in both individual and joint decision making. It supports interactive communication in two senses. First, each party can use WAS by itself, to examine various water-allocation scenarios, obtaining feedback information about the implications of each scenario on its country's domestic water economy and consequently on its other objectives. Second, the two parties can perform a similar analysis jointly, in search of joint gains. While exploring scenarios for resolving the allocation of the joint water resources and negotiating "around" the WAS model, the parties have an opportunity to communicate, evaluate each other's expectations and goals, and interact in a manner that is less distributive and more integrative.

Even though this work is concerned with bilateral negotiations over international water resources, we believe that the same principles can be applied also to multi-lateral negotiations. In that case, however, negotiation elements specific for multi-party situations, like possibility of coalition formation, would have to be accounted for and adequately modeled.

The NSS was tested in two types of simulation experiments. The first was performed as simulated negotiations with real actors who played a ’negotiation game’ based on a case study. Half of the participants performed the exercise with the NSS and the other half without, and the results were compared and statistically analyzed. These exercises were limited by the duration of the ’game’ and by the computer skills of the participants, so that the efficacy of only a part of the NSS features could be assessed. The second type of experiments were performed with 'simulated actors', in which the initial preference structures were elicited from ’random participants’, while the remaining dynamics of the ’negotiating parties’ was simulated by the researcher. The aim of these latter experiments was to test and explore in detail the role and capabilities of WAS within the framework of the NSS, which was not possible in the simulations with real actors.

Jointly, the two types of experiments showed that economic considerations can represent an attractive way of "enlarging the pie” in negotiations over the allocation of water resources. The individual decision support provided by the AHP algorithm assisted the parties in structuring and weighing their preferences with respect to the negotiation problem. The WAS model and the other NSS components were shown to have the potential to improve the communication and information exchange between the parties, as well as their creativity in searching for alternative negotiation solutions.

List of Symbols

a	Negotiation alternative
$i = \{A,B\}$	Index, for two negotiation parties (countries, entities), A and B
$Q_i(a)$	Quantity of water from the disputed resource [mcm/y] allocated to party *i*, by alternative *a*
$v_i(a)$	Net economic gain to party *i* resulting from alternative *a*
$u_i^j(a)$	Subjective measure (score) of the degree to which alternative *a* satisfies objective *j* of party *i*
Q_{DS}	Average annual renewable quantity of water in the disputed source
$q_i(a)$	WAS-optimal quantity of water from the disputed resource, to be supplied to the consumers in *i*
$V_i(a)$	Annual net economic benefit to party *i* from the use of water allocated to it by alternative *a*.
Q_i'	Annual renewable quantity of water available to *i* which is not subject of negotiation.
$V_i(a^s)$	Annual net economic benefit to *i* resulting from alternative *a* and domestic water-allocation scenario *s*
a_r	Reference alternative
$\Delta v_i(a_r,a)$	Change in the net benefit to party *i* obtained by selecting *a* over a_r
ΔQ	Quantity of water transferred from one party to the other
$v_{SP,\, i\rightarrow j,}$	Side payment (transferred from party *i* to party *j*)
$k_j^i(a_k, a_l)$	Ratio of the weights assigned two alternatives, *a*, and a_l (by party *i*, according to his negotiation objective, *j*)
o^i_j	Negotiation objective *j* of party *i*
$c^i(o_1,o_2)$	Ratio of the relative importance party *i* assigns to its two objectives, o_1 and o_2.
w_i^j	The weight, or the relative importance of objective ***j*** to party ***i***
u_j	is the score of alternative ***a*** with respect to objective o^i_j,
U^t_A, U^t_B	Subjective utility functions of the negotiating parties ***A*** and ***B***, in negotiation iteration ***t***

List of Abbreviations

NSS	Negotiation Support System
WAS	Water Allocation System
DSS	Decision Support System
IDS	Individual Decision Support
BATNA	Best Alternative to Negotiated Agreement
AHP	Analytic Hierarchy Process
ERA	Experiments with real actors
ESA	Exercise with simulated actors
W/NSS	Simulations with the NSS
WO/NSS	Simulations without the NSS
W/AGREE	Simulations exercises with the agreement
WO/AGREE	Simulation exercises without the agreement
NLR	Nested Linear Regression
AC	Cronbah’s Alpha

Chapter 1
Introduction

1.1 Background

1.1.1 Water scarcity as a cause for international conflicts

Water scarcity is a term that relates to the lack of fresh water for human (urban, agricultural, industrial) consumption due to insufficient quantity and/or inadequate quality of fresh water. About 40 percent of the World's population has already been suffering from different levels of water scarcity, and the projections indicate that by year 2025, it will affect about 60 percent of the global population (Shmueli et al., 1997). Water scarcity is the result of natural, hydrological and climatic, and human factors. Basic characteristics of water and water cycle which increase the potential for water scarcity are:

1. *Uneven distribution over the globe*. While some parts of the world suffer from excess rain and frequent floods, about 60 percent of the Earth's surface are regions where quantities of fresh water are insufficient to meet the local needs.
2. *Seasonal variability*. Some regions of the world face a high seasonal variability of available quantities of fresh water. Arid zones have to deal with a lack of water in the periods of the year when the need for fresh water is the highest.
3. *Global climatic change*. During the last few decades, the Earth's climate has been going through a global change that is likely to affect water availability in many ways (Gleick, 1993; Kliot et al., 1996). One of the threats of this climatic change is the increase in the quantities of fresh waters lost to evaporation, as a result of higher average temperatures.

The constant increase in global population is putting an intensive pressure on the world's water resources. Demand for water for domestic and industrial uses and agricultural production is rapidly increasing. As more and more people reach a higher standard of living, per capita water consumption is likely to continue to increase. In addition, wastes from a variety of human activities have been polluting surface and underground water resources. Degradation of water quality is another factor that limits the availability of fresh waters.

New sources of water are becoming scarce and more difficult to develop: higher and more expensive technologies are required for their planning and operation. According to the United Nations Commission on Sustainable Development (1997), water shortages in this century are likely to restrain economic and social development in many parts of the world, and be a potential resource of international conflicts.

The potential for a water scarcity problem has been referred to as 'water vulnerability'. Different indices have been used for the estimation of a country's, or a region's water vulnerability. Shmueli et al. (1997), estimate that countries whose present water withdrawals exceed one third of their total renewable supply are considered being at a high level of water vulnerability. A study of the United Nations (1997) defines high stress countries as those, which consume more than 40% percent of their fresh water supplies for agricultural, industrial or domestic use each year, and medium-high stress countries as those which use from 20 to 40 percent. Falkenmark (1994) uses the annual per-capita water availability below 1000 mc per person per year as the indicator of a potential for water scarcity. According to this measure, the Middle East countries are at a high risk.

As water scarcity becomes an inevitable reality in many countries, and the need for fresh water resources is constantly increasing, the problem of international waters becomes more and more acute. According to the United Nations Register of International Rivers (1978), there are more than two hundred sixty international river systems worldwide (these account for about 47 percent of the Earth's land area). Fifty-three international basins are shared by three or more countries. Riparian countries in many of these basins have already been involved in different types of international disputes regarding the shared waters. Problems arising in international watersheds include a wide range of navigational, flood regulation, environmental quality, and, as probably the most sensitive, water scarcity issues.

When dealing with water scarcity problems, governments frequently take decisions to increase withdrawals from the shared water resource, without considering the needs of their neighboring countries. Increased withdrawals, diversions, or other regulations in most cases invoke or exacerbate water scarcity problems in downstream countries. In arid regions, where already exists a traditional competition over water, such actions are likely to invoke international disputes (Dinar et al., 1997). When facing a water scarcity or other water management problems, governments take unilateral actions without considering the needs of other riparian countries. Typical conflicts are between upstream and downstream riparians of an international watershed: the upstream riparians are in the position to control the quantity and the quality of water flowing downstream, and can directly affect the supply to their downstream co-riparians.

1.1.2 Overview of international water conflicts

Conflicts over international waters have been the subject of a number of studies and published works (Wolf, 1995; Just and Netanyahu, 1998; Kliot et al., 1996). Even though more than 280 international water treaties have been signed to date, there are still many unresolved cases.

Water issue has been one of the several causes for the historical regional tension among the countries of the Middle East. Jordan has been objecting to the construction and operation of Syrian dams on the Yarmouk, the major tributary of the Jordan River. The Yarmouk has also been a conflicting issue between Jordan and Israel. Control and allocation of the Jordan River and its sources, as well as the use of the aquifers underlying the West Bank have been the cause of conflict between Israel and its other neighbors too. In two occasions, Syria and Israel have been involved in armed conflicts (Wolf, 1995).

About 90 percent of the water of the Tigris and the Euphrates originate in Turkey. In 1960s, Turkey started with the construction of the GAP system on the Euphrates and Tigris. The system includes 22 dams and 19 hydropower stations (Kliot et al., 1996), and has the potential of reducing flows as much as 40 percent to Syria and 80 percent to Iraq. In 1970s, when Syria also started with larger withdrawals of the Euphrates flows for irrigation, Iraq threatened by military attacks.

After the 1947 partition of the Indian subcontinent to India and Pakistan, India remained with the control of the Indus waters supplying Pakistan's irrigation canals. In 1948, India diverted these waters and initiated a series of conflicts between the two riparians which, in few occasions, threatened to lead to war. India, as the upstream riparian on the Ganges River, has also initiated water development projects that have been seriously reducing water supplies to the downstream Bangladesh (Wolf, http://www.transboundarywaters.orst.edu).

The Aral Sea in Central Asia, the fourth largest lake on the Earth, has shrunk by more than 70 percent since 1960 and has become highly polluted. Today, the riparians, the five former republics of the Soviet Union (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan), have been struggling to share the lake (Wolf, http://www. transboundarywaters.orst.edu).

Other examples of international disputes involve the following river systems (Kliot et al. 1996): Columbia (between the United States and Canada), Rio Grande/Rio Bravo (between the United States and Mexico), La Plata (Argentina and Brazil vs. Uruguay, Paraguay and Bolivia), and others.

1.1.3 Claims to water

There is no international law, which, in an unambiguous way, determines the allocation of water resources shared by independent countries or political entities. In the absence of a binding rule, parties involved in conflicts over international waters use various criteria to support their claims. The most frequent are claims according to *geography*, e.g., from where a river or aquifer originates and how much of that territory falls within a certain state, and *chronology*, that is, who has been the longest consumer of the water from the resource (Helfgott, 1995).

In disputes between upstream and downstream riparians of a single watershed, upstream countries often relay on the "doctrine of absolute sovereignty". This extreme principle claims that a state has absolute rights to water within its territory (the claims of Turkey and Ethiopia in the cases of the Euphrates and the Nile, respectively). Downstream countries usually claim their rights based on the "doctrine of absolute integrity". This principle suggests that every riparian state is entitled to the natural flow of a river system crossing its borders. In arid regions, the down-stream riparian usually has an older infrastructure that is in his interest to defend (the claims of Iraq and Egypt in the case of the Euphrates and the Nile, respectively). The principle that assigns greater rights to the older use is referred to as *prior appropriation*.

Even though often used as claims, these extreme doctrines have never been a basis for an international water treaty. Most of the treaties were signed when disputes escalated to the point were the parties had to make a choice between compromising or entering a war. Proclivity of the most of the disputed riparian countries to avoid armed conflicts, usually supported by the supervision of a neutral, third party (international organization or another country), usually makes them move toward compromising alternatives.

1.1.4 International law

Since the end of the World War I, international law institutions have tried to shape the guidelines for the intensive use of water resources, focusing especially on the international watersheds. In 1966, the International Law Association adopted the Helsinki Rules, which introduced the concept of a “drainage basin” and the general guidelines for “reasonable and equitable” sharing of a common waterway. While Article IV of the Helsinki Rules states that “Each basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial use of the waters of an international basin”, Article V lists the factors that should be accounted for when defining what is “reasonable and equitable”. Among these are: basins geography, hydrology, climate, past and present water utilization, economic and social needs of the riparians, population, comparative costs of alternative resources, availability of other resources, avoidance of waste, the degree to which a state’s needs may be satisfied without causing substantial harm to a co-basin state. The Rules suggest that eventual international conflicts should be resolved by compensation.

In 1997, the UN General Assembly adopted the “Convention on the law of the Non-Navigational Uses of the International Watercourses”, which was put up by the International Law Commission (ILC, the General Assembly legal advisory body). This Convention provided a framework for the management of the international waters. The term “international watercourse” was defined and both glaciers and confined aquifers were included into the codification. Similar to the Helsinki Rules, the Convention requires riparian states to communicate and cooperate, exchange information, protect of ecosystems, and notify eventual emergency situations. "Reasonable and equitable use" within each watercourse state, with the obligation not to cause significant harm, is the basis of the vague recommendation for allocation problems. One of the problematic facts of this Convention is that it does not represent the rights of the political entities who do not have a state with internationally recognized borders, but might claim water rights (the Palestinians along the Jordan River, or the Kurds along the Euphrates).

The most updated document that relates to the problems of allocation of international waters, is the last revision of the Helsinki Rules, the Berlin Rules (International Law Association, 2004) These new rules do not change the underlying situation, namely that there is no definitive set of rules for allocation of water, and the same considerations still appear. The document addresses the following issues:

1. Equitable utilization;
2. Protection of the aquatic and aquatic related environments;
3. Navigation;
4. Extreme situations related to highly polluting accidents, droughts, and flood control;
5. Protection of Water Resources and Water Installations during Armed Conflicts;
6. Administration of an International Drainage Basin;
7. Public Participation, as a means for protection of the interests of communities affected by water projects;
8. Legal Remedies relate to responsibilities of each riparian state in the case its actions in the international drainage basin cause environmental harm or damage to persons in another state;

As is stated in the document, the codification that relates to prevention and settlements of disputes is yet to be developed. The relevant articles are:

Article 11: Cooperation. Basin states shall cooperate in good faith in the management of water for the mutual benefit of the participating States, respecting the sovereign equality and territorial integrity of each State.

Article 12: Equitable Utilization. Basin States are entitled in their respective territories to make an equitable use of the waters of an international drainage basin, subject to the duty to manage the waters of the international drainage basin, separately or jointly, in an equitable and reasonable manner taking into account the interests of each basin State.

Article 16: Avoidance of Trans-boundary Harm. A basin State shall refrain from and prevent acts or omissions within its territory that causes significant harm of any kind to another basin State, except insofar as such harm is necessitated to accomplish an equitable and reasonable use as provided in Article 12 and is otherwise consistent with these Rules.

The document gives guidelines for the determination of an *equitable and reasonable use*. It lists the relevant factors to be included in the consideration for each particular international watershed. Among these are: geographic, hydrogeologic, hydrologic, climatic, ecological features of the drainage basin including the extent of the drainage area in the territory of each basin State and the contribution of each basin state to the waters of the basin; the past, present, and foreseeable future uses of the waters of the basin and other economic and social needs in each basin State; ecological integrity of the basin.

Although the International Law Association Rules and the UN Convention on the law of Non-Navigational Uses of International Water Resources expand the range of possible resolutions to international water disputes, they do not provide a clear definition of property rights or unambiguous directions for water allocation. The more powerful country, or the country with the position advantageous over others in any (for that matter) useful way, still has the opportunity to influence the arrangements within an international watershed. The most influencing riparian controls and uses the water resource with little concern for how it affects the others. Another problem with the ILA Rules and the ILC Convention is that they are not binding. There is no international organization authorized to apply legal or other measures on the riparian countries which do not respect them.

1.1.5 Characteristics of negotiation processes and the quality of negotiated agreements

Negotiations have been the most common way of the attempts to resolve disputes and avoid armed conflicts over shared water resources (Kliot et al., 1996). During the last two centuries, more than 280 treaties have been singed over international water resources. Among 145 treaties signed in the period between 1874 to 1996 which are included in the Transboundary Freshwater Dispute Database (Wolf, 1999), twenty relate to non-consumptional issues (flood control, navigation, or fishing), while all others mainly relate to distribution of water for consumption (53 treaties), hydroelectric generation (57), industrial uses (9), and pollution (6).

Negotiations over shared waters last long periods of time. It took ten years of negotiations to settle the Indus River dispute, 30 years for the Ganges, 40 for the dispute over the Jordan River (Wolf, http://www.transboundarywaters.orst.edu). During such long periods, due to inadequate distribution and/or pollution, the quality and quantity of water may seriously deteriorate and become inadequate for the maintenance of the ecosystems and use by present and future populations (for example, deterioration of the lower parts of the Jordan and the Nile Rivers; Gleick, 1993).

The reasons for long duration of the disputes and negotiations are in the very nature of the issues at stake. When scarce, water resources become strategically very important. A country which depends on an international water resource, has a high priority to assure the control over as large a share of that resource as possible. The negotiations are conducted as a simple bargaining process, in which each party selfishly pursues its own interests. The communication between the parties is burdened by the lack of mutual confidence and unwillingness to reveal information and relevant data. Possession of relevant information and data is of strategic importance. The country in the possession of better data is able to calculate the possible outcomes from potential negotiation solutions and to better access potential risks. Furthermore, there usually exists a disagreement about geographical, historical, hydrological and other facts that are actually in the core of the negotiated issues (borders, rights, current and future demand for water versus availability of water, etc.). The countries may also differ in their ability to understand the meteorological and hydrological processes in the shared watershed. Different scientific approaches may be used to access the present and future quantities and qualities of the available water.

The countries are often inclined to adopt or interpret certain ‘theories’ in the way that will best serve their interests. International negotiations over water resources are often supported, by the means of facilitation or mediation, by a neutral party - a country or international organization (Just and Netanyahu, 1998). The task of this party is to improve the communication and exchange of information between the negotiators, and to assist them in searching for a way to reconcile their conflicting interests.

Riparians of an international watershed are rarely ready to let other countries or, "third", neutral parties interfere with their domestic water policy, and are usually, not willing to establish a cooperative management of shared waters.

When reached, agreements over shared waters are usually strongly affected by the power asymmetry between the parties. The party that is in a better strategic position usually succeeds in compelling the acceptance of its interests on its counterpart. In the other hand, no international law, regulation or institution can enforce the countries to respect the achieved agreement.

Just and Netanyahu (1988) lists some of the basic obstacles to cooperative management of shared waters:

Sources of the obstacles to cooperation:

- *Competing uses and absence of common goals.* In some countries water is a matter of survival, while in others it is a matter of life quality improvement;
- *Desire for food security and self*-sufficiency in arid and semi-arid regions;
- *Different levels of economic development* result in different abilities to invest in national and international water projects that would improve water utilization;
- *Deferent perceptions of the need for the environmental quality*. Countries that depend on the same water resources often differ in the way they deal with water and environmental quality issues;
- *Different cultures, histories and different symbolic meanings of water*. Water is of an important symbolic meaning to many nations. Often, it is perceived as too important or too sacred to have its natural regime changed;
- *Different social values (meanings) of water*. In some countries, the government subsidizes the price of water for the consumers in certain sectors, often agriculture. Subsidies increase the demand for water and have traditionally been perceived as harmful to other riparian countries;

- *History of conflicts and mistrust*. Countries in some international watersheds have been involved in a long history of conflicts related to different issues that may or may not include water. Mistrust developed between these countries prevents them from entering any kind of joint projects;
- *Uncertain climatic changes and unwillingness to comply with long-term commitments*.

Since water is of a high social and strategic importance to disputed parties they conduct the negotiations in a zero-sum (win-lose) game stile, pursuing their own (national) interests and goals. Because of the history of conflicts and mistrust, the communication between the parties is burdened by the lack of mutual confidence so that recognition of eventual joint interests is extremely difficult. Publicly, water is perceived and discussed in quantities only – the more one party gains, the more others lose. Bargaining in such manner leaves little or no space for exploring alternative solutions that will simultaneously improve positions of all involved parties. If (at all) an agreement is reached, it is usually affected by the power balance between the parties so that, at least one of them, leaves the negotiation table unsatisfied.

1.1.6 Alternative Dispute Resolution

As a result of the constant, increasing trend in the demand for fresh water and pressure on the shared water resources, there has been an increase in the awareness of the water-based inter-national dependence among the riparian states. According to the studies of Delli Priscoli (1996), most of the countries realize that as constraints on the resource grow, the opportunity costs for not cooperating are becoming clearer. However, the imperative need of the nations to control the water resources puts a major constraint on reaching a cooperative agreement that would be efficient and beneficial to all parties involved. The same author states that there is a need for an international water resources management mechanism that will give incentive for cooperation. Such a mechanism should assure ‘better off’ positions to all parties and provide alternative means for ‘control’ over the resource. Traditional means have been taping or diversion by upstream and military interventions by downstream countries. Instead, a mechanism should be offered that will give the right and opportunity to all the riparians to take part and control the decision-making process within a joint, cooperative, and beneficial management of the shared resource.

Problematic management of international water resources and related conflicts have been a subject of interest of different fields, like international law, economics, sociology, psychology, and other. A number of published works analyze the causes of success or failure of international 'water' negotiations from different aspects (Dinar et al., 1997, Beach et al., 1998, Bazerman et al., 1997). During the last two decades, there have been attempts to assess the potential of Alternative Dispute Resolution (ADR) approach in the specific area of environmental conflicts. ADR approach includes a wade rage of techniques with which the parties to disputes voluntarily seek to achieve a settlement of issues (Bingham and Stedman, 1999). Most are 'collaborative techniques', meaning that the goal of the parties is to reach a voluntary agreement. ADR techniques include dialogue and negotiation, as processes of direct communication. When assisted by a neutral party, such dialogues become processes of mediation, facilitation or arbitration, depending on the degree of the neutral party's involvement.

ADR techniques are alternative to adversarial processes that usually result in 'win-lose' solutions. They involve application of theories and procedures designed to achieve an agreement that is acceptable and satisfying to all parties. Various ADR techniques prescribe several common rules to the disputed parties:

- educate each other about fundamental interests
- jointly identify options that could be mutually beneficial
- agree on criteria for identifying jointly acceptable solutions
- consider a wide range of alternative solutions.

Delli Priscoli (2003) gives the advantages of the application of ADR approach to water resources management in general, and to international water disputes, in particular. The aim of all ADR techniques is to move the disputed parties from a *position*-based to an *interest*-based dialogue. Position-based bargaining starts out by parties taking fixed positions. In order to reach an agreement, the parties have to make concessions, until they reach a mutually acceptable solution. Such agreement is a compromise, which does not satisfy all of the parties' needs – it meets just enough to be accepted as (no more than) a tolerable agreement. As is typical for disputes over water resources, people's positions are not necessarily the same as their interests. For example, if a country takes the position that it requires the right to use most (or all) of the annual availability of water in a source shared with another country, it is doing so to meet its various interests, one of which may be assuring a safe water supply. ADR approach assumes that there might be more than one way to satisfy the interests of a disputed party, as in this particular example, to balance water demand and water supply within a country. Delli Priscoli (2003) concludes that when parties concentrate on positions, any concession is perceived as a loss; when concentrating on interests, the parties may explore and find various ways to meet these interests, some of which may be mutually acceptable.

ADR techniques and procedures are designed and/or selected to provide the best assistance in each particular dispute. Disputes can be result of conflicts over values, interests, relationship, or data, or, as is usually the case in international water disputes, they can have the combined features of several types of conflicts. When voluntarily accepted, ADR techniques have potential to improve the communication and information exchange among the disputed parties, to assist them in recognizing their own and understanding others' interests and needs, and to provide the opportunities for exploring various solutions to the conflict. Assumption of the ADR approach is that the outcome, which does not satisfy at least up to a certain degree, all (or most) of the needs of the disputed parties, is probably unstable. On the contrary, when all parties walk away satisfied with the outcome, they all have a stake in making the resolution work and last (Delli Priscoli, 2003).

1.1.7 Economic solutions to water scarcity

Water scarcity often reflects the problems in the management and allocation of water resources within individual countries. Allocation of water among different users on domestic level is, in most cases, subject to political decisions. In many countries throughout the world, governmental water policies seem biased toward certain sectors, mostly agriculture (Berk and Lipov, 1994). Such water policies are usually designed without a proper consideration of the economic value of water. Water is treated as an economically inexpensive commodity, and prices charged to certain users do not reflect real prices. According to Fishelson (1992), a large fraction of water allocated to agriculture is producing little if any value net of cost. Reduction in prices contributes to over-pumping and deterioration of natural water resources. Manny water economists agree that misallocation of water, and especially a water-policy that favors certain water-use sectors, is likely to cause artificial water shortages (Becker and Zeitouni, 1998, Jordan, 1999, Zeitouni et al., 1994).

Water economists argue that there are major differences between water-sector policies pursued by governments and the theoretically (economically) efficient water-allocation models (Berk and Lipov, 1994). Economic efficiency of water allocation is reflected in the system of prices: prices charged to consumers, supply costs, and the real value of water. Prices charged to consumers should not be lower than the sum of the marginal cost of production and the marginal cost of distribution. Uses of water at prices lower than the marginal supply cost result in overexploitation of water resources and are economically inefficient.

According to the economic approach, a real price of water should, beside extraction, delivery, and capital costs, reflect the *scarcity rent* of water at the source, too. Scarcity rent takes into account the user cost due to scarcity. For example, consumers may be willing to pay a positive value for additional unit of water from an already exhausted resource (Fisher et al., 2002). Tietenberg (1992) and Jordan (1999) go even further by arguing that scarcity rent should not reflect only the existing, but the *potential* scarcity of water as well: using large amounts of water to keep grass green may be appropriate for a region with large replenishable water supplies, but not when it denies drinking water to future generations. If prices do not take this higher scarcity value into account, inefficiency is imposed on the future – too much water us consumed today (Jordan, 1999).

Water economists relate to water as an economic good and propose allocation of water through a market mechanism. A market mechanism treats water as an *ordinary economic good*, and balances the marginal cost of the supply of water with the marginal demand. The marginal demand of consumers is expressed through their willingness to purchase additional unit of water. However, there are serious objectives to implementation of a pure market mechanism on domestic water allocation problems. According to the principle of marginal demand, if the poor cannot pay as much for a unit of water as the rich, they should get less water. Opponents to such approach argue that water is a *public good*, and that safe water is a basic need and should be available at reasonable levels to everyone (DellaPenna, 1995). Others believe that water serves important ecological, environmental, and aesthetic benefits in many cases, and should not be allocated to other uses simply on grounds of willingness to pay: at least up to some minimal level of availability, water is a social good whose availability to certain consumers and for certain purposes at prices below market value provides benefits to society as a whole (reference). From the economic perspective, this approach relates to water as to a *merit good,* which consumers should be encouraged and helped to consume, up to some quantities, for example, by a subsidy.

Perry et al. (1997) summarize different relations to water as a good (basic human need, a merit good, or an ordinary private good) by suggesting that water satisfies many different needs, and has properties that make it both a private and a public good. Therefore,"…a proper water management requires much more sophisticated form of analysis than that adopted by proponents either of basic needs or of free markets. Water policy must be formulated in terms of multi-objective decision-making, recognizing that the relevance and importance of various values of water will vary substantially over different conditions".

In the last decade, there have been many attempts to apply the basic concepts of market theory to water allocation problems. These concepts are not limited to domestic water policies. Beker and Zeitouni (1998) analyzed the efficiency of a decentralized market of water for Israel and the PNA and compared it with the actual allocation in terms of the welfare losses. Yaron (1994) related to the arguments that a pure market mechanism may lead to drastic changes and deviations from *status quo* in agriculture which needs a long run supply reliability: he suggested an allocation-pricing policy based on a mix of quota system with market mechanism, with the later applied only at the marginal segment of the quotas. He proposed high water prices at the quota margins and gradual adjustment of the quotas over the years in order to increase the efficiency of water use over time and at the same time avoid drastic changes in allocation.

We propose a collaborative Negotiation Support System (NSS) as a dispute resolution framework, to assist the parties in searching for feasible and satisfying solutions to management of the shared resources. The NSS incorporates some basic concepts of a water market system to help in determining an optimal allocation of an international water resource. These concepts are combined with approaches adopted from Decision and Game Theories, as well as ADR techniques, to provide the negotiators with support and opportunities to account for the plural meanings of water to their societies.

1.2 Overview of negotiation support models

Kersten (1985) defines group decisions and negotiations as situations which engage two or more participants in two types of activities: communication and decision-making. Negotiation support techniques are aimed at assisting the participants to form, represent and analyze arguments, exchange information (including offers), and make compromise decisions.

Formal methods and models for group decisions and negotiations evolved from decision analytic methods for individual decision making (Kersten, 1985, Fraser and Hipel, 1984, Hipel and Fraser, 1991).

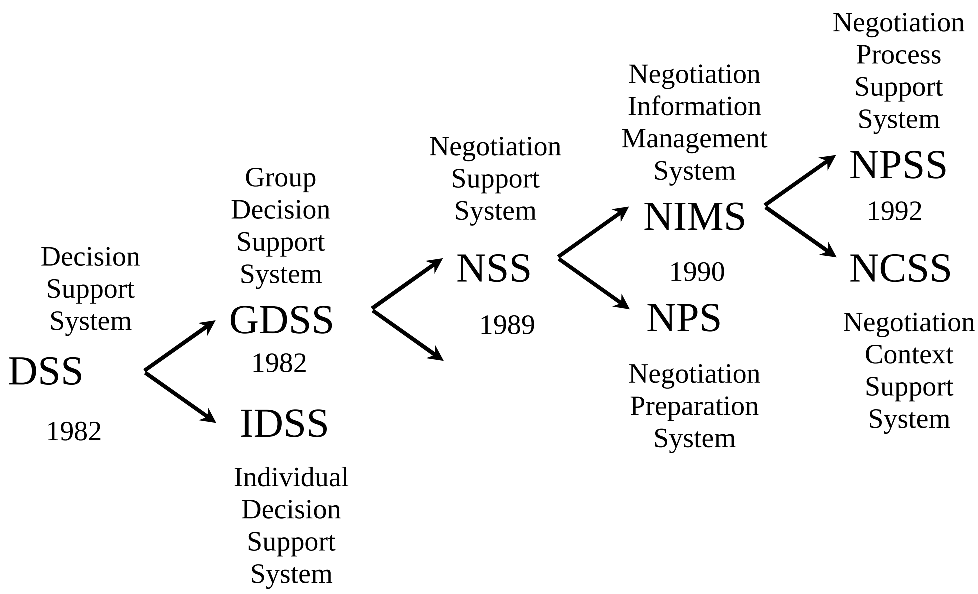

Figure 1.2.1: Evolution of Decision and Negotiation Support Systems (Thiessen et al., 1992)

Computer based tools and aids have been developed to assist the participants in group decision making and negotiations. Negotiation Support System (NSS) is a term used in the literature on interactive computer programs for multi-objective conflict resolution (Fraser and Hipel 1984; Kersten, 1988). Negotiation Support Systems are a specific type of Group Decision Support Systems (Figure 1.2.1) designed for providing assistance in situations where there is disagreement among various parties as to what decision to adopt (Thiessen et al., 1992). They can be categorized according to their functions in the following way (Nyhart and Goeltner, 1987):

a. Negotiations Preparation Systems, which operate away from the negotiation table and assist one party only.

b. Negotiation Information Management Systems that can be further divided into:

- Context Support Systems, which are used in the case of negotiation over design, management or operation of a system. Context models simulate the behavior of the system being designed and can be used to analyze its performance under different circumstances.
- Process Support Systems, which are concerned with the dynamics or procedure of the negotiation process (Thiessen, Loucks and Stedinger, 1992). Process support systems are designed to assist the process of negotiations by increasing the likelihood of identifying one or more mutually agreeable proposals when a potential region of agreements exists. They can help identify better solutions than those that would have been found without their use.

NSSs have been developed for used in practice, as well as in training and research. PERSUEDER (Sycara, 1993) is a package for the group decision support, which uses artificial intelligence techniques (case-based reasoning) and decision theory methods (multi-attribute utilities). It is able to incrementally propose modifications to a proposal, to help parties narrow their divergent views. It helps them communicate arguments and justifications and also suggests plausible arguments. It is an intelligent DSS, capable of learning from past negotiation cases, and uses this knowledge, as well as participants' preferences, in determining the proposed compromise. ICONSnet (http://www.icons.umd.edu) is a Web-based simulation software developed specifically to support on-line negotiations and related activities. It is the basis of the International Communication and Negotiation Simulations (ICONS) Project which offers opportunities for students from around the world to participate in Internet-based negotiation simulations. ICONSnet was designed to enhance interactive learning by encouraging the development of critical thinking skills and an awareness of cultural differences in approaches to negotiation and problem solving.

Some NSSs have been designed to support a third party mediator or to act as mediators themselves by suggesting solutions to the negotiation problem. They are basically process support systems but some of them have also the features of a negotiation preparation system. MEDIATOR (Jarke et al., 1987) is a package which uses a data base-centered approach to consensus seeking. Each participant uses a DSS to perform an individual utility analysis of the negotiation problem. A mediator then assists in consensus seeking by aiding the players in building a group joint problem representation of the negotiation problem. MEDIATOR has been applied to hostage crises (Jarke et al., 1987), in which a human mediator creates the database based upon his understanding of the positions of extremely hostile parties. NEGO (Kersten, 1985) is an interactive system which uses multi-objective linear programming techniques to establish proposals from each of the individual participants. It then forms a sequence of compromise proposals based on relaxed participant demands. The problem is solved when a compromise proposal is produced that satisfies the revised set of demands.

Support for individual negotiators includes stand-alone DSSs which are designed to aid one party in negotiation preparation and/or in determining a successful course of action. This group includes Decision Analysis Systems like the Graph Model for Conflict Resolution (GMCR, Hipel et al., 1999), the model which helps the user to analyze strategically whether to take part in negotiations, and to decide what choices to make during negotiations. It requires the user to assess the interests of both sides and uses the information to help determine what to do, offer or threaten, and how to respond to offers, actions and threats by the other side. NEGOTIATOR (Bui, 1992) can be used as an individual DSS or as part of a group decision support system when integrated with communication software. It utilizes multi-attribute utility methodology and neural network learning techniques. GENIE (Wilkenfeld et al., 1995) is an individual negotiation support system that can be used by all participating decision makers in a crisis situation. Each application by a player operates individually, without any direct relation to applications of other players. A major task of GENIE is to present a complex negotiation model to the user in an easily understandable and organized manner. A user can explore his own various negotiation positions. It also allows a negotiator to evaluate quickly opponent proposals during actual negotiations. GENIE was experimentally evaluated in a hostage-crises simulation with a scenario based on a hypothetical hijacking of a commercial aircraft which involved three parties negotiating in triple bilateral negotiations: the highjackers, the country of the hostages, and a neutral mediator.

1.2.1 Context and process support in resolution of disputes over water resources

Computer programs that provide detailed simulations of water resources systems simulate hydraulic and hydrologic processes. Such are the programs developed by the US Army Corps of Engineers' Hydraulic Engineering Center, such as HEC-HMS, HEC-RAS, and HEC-5 (The US Army Corps of Engineers, http://www.hec.usace.army.mil), used to model runoff, analyze flood flows, and understand behavior in reservoirs, RiverWare, for river and reservoir modeling (Zagona et al., 2001), and IRAS - Interactive River-Aquifer Simulation (Loucks et al., 1995). These models provide support necessary for understanding the physical system and for evaluation of proposed changes, and have been used for context support for group decisions and negotiations.

ICANS (Interactive Computer-Assisted Negotiation Support System, Thiessen et al., 1992) is an example of a process support system with application to water resource conflicts. Based on information provided to the program, in confidence, by each party, it assists the parties in identifying feasible alternatives, if any exist, that should be preferred by each party in the absence of a negotiated agreement. If such alternatives do not exist, the program can help parties develop counter proposals. Through a series of iterations in which each party's input data, assumptions, and preferences may change, ICANS can aid the parties in their search for a mutually acceptable and preferred agreement.

Examples of systems that integrate both context and process support include the CRSS (Conflict Resolution Support System, Rajasekaram, et al., 2002), a computerized technical support system developed to aid conflict resolution through five functional activities: communication, problem formulation, data gathering and information generation, information sharing and evaluation of consequences. The basic tools included in the CRSS are tools for multi-purpose reservoir operation, river flow routing, multi-criteria decision-making, and spatial data analysis.

Shared Vision Modeling (Palmer et al., 1993) is an approach based on the premise that "models must reflect the effected parties' perspective of their water resources system. It requires identification of the stakeholders involved in the system and recognition of their primary concerns. The approach is combined with STELLA®II (High Performance Systems, Inc.), which is an object-oriented, graphical modeling environment, and can be used to simulate any water system. The stakeholders receive training in STELLA®II, and develop a model of the physical system, with which they perform simulation of proposed alternatives and examine the outcomes and consequences of each. The model is considered joint property of all stakeholders, and is available during the process of negotiation and conflict resolution.

OASIS (HydroLogics, Inc.) software is a tool that enables parties with diverse and often conflicting goals - such as cities, power facilities, environmentalists, and agriculturalists - to work together to develop operating policies and solutions that mutually satisfy their diverse objectives. It is capable of modeling virtually any water system in the world, from small and simple to large and complex. OASIS is combination of a graphical user interface and OCL™ (Operation Control Language) which enables data to be entered as a series of rules and constraints, and allows the interested parties to model systems in planning or negotiation sessions and see results almost immediately.

The common features of these and similar models which provide both context and process support resolution of conflicts related to water resources, are:

1) they enable simulation of physical water systems and thus provide means for exploring and enlarging the space of alternative solutions to the conflict;

2) they concentrate on (physical) feasibility of analyzed alternatives, but do not provide an objective measure for the ‘quality’ of these alternatives;

3) they require a joint definition of the problem, and a joint agreement on the constraints imposed on each alternative solution;

4) they do not require detailed structuring and understanding of individual preference structures; and

5) they do not provide a structural framework for the selection of a single (the best) alternative solution.

Our NSS belongs to the category of the last three models: it is aimed to support both context and process of negotiations over allocation of international waters. The concepts and design of the NSS, as well as the manner in which it deals with the above issues, will be addressed in next chapters.

1.3 Aims of the research

The aim of this thesis is to design a negotiation support system (NSS) for parties who represent politically independent entities with claims to the same water resource. According to the overview of the real-world cases, the parties to negotiations over international waters approach the negotiation process with a goal to ensure for themselves as much as possible of the disputed resource. Thus their basic interests are mutually conflicting. Frequently, the negotiations are burdened by a long-standing mistrust or even open hostility.

In terms of negotiation and game theories, such negotiation processes are defined as *distributive bargaining*. Distributive bargaining focuses on allocation of “fixed” resources between the parties, fundamentally a *“zero-sum game”*: any gain of one party represents a loss to the other party (water allocated to one party is not available to the other). The outcome of the game represents a win-lose situation, where usually the party that has the power forces the other party to accept its demands, or at least a major part thereof.

As opposed to distributive bargaining, *integrative bargaining* is, by definition, a process wherein the parties search for common or complementary interests, and explore ways to expand the options which can be shared by the parties, either by expanding the resource base and/or by incorporating complementary interests into the common arena (*Raiffa, 1982*). Instead of a forcing strategy, in an integrative bargaining the focus is on a so-called "fostering" strategy that is based on the premise that once the true and full interests of the parties are identified, "win-win" solutions can be found which leave both parties better situated and more satisfied.

According to Ury et al. (1993), parties involved in a dispute can base their negotiating strategies on one of three approaches: rights, power, or interests. Focusing on *rights* means that parties try to determine how to resolve the dispute by applying some accepted law or standard of fairness. Since there is no international law that regulates definitively the allocation of shared waters (see 1.1.4) and standards for fairness are usually perceived differently by the parties, this approach is likely to lead to a distributive, win-lose agreement, or to a compromise that does not realize potential integrative gains. Focusing on *power* means that each party tries to convince the other to make concessions while using some kind of threat. In international water-disputes, power inequities strongly affect the outcome of negotiations, often with a party who sees in the preservation of the status quo a prevailing interest. Veto by one participant is sufficient to paralyze the process. A power approach generally leads to a distributive agreement, which is likely to evoke new or prolong existing disputes. In most cases of negotiations over shared waters, agreements, if reached, were based on "rights" or "power".

According to the same authors (Ury et al., 1993), in order to achieve an integrative and mutually beneficial agreement, the parties need to focus on *interests*, rather than merely on *positions*. Focusing on interests means that the parties try to learn each other's needs, concerns, and priorities, and attempt to reconcile them in the search for an agreement. Negotiations between sovereign entities who claim rights to the same water resource are usually burdened by a lack of mutual confidence. National integrity and security are of a primary concern, and revealing the priorities and concerns to the counterpart is not perceived as a safe and promising strategy. The crucial importance of water resources makes each party pursue it's own needs in a self-oriented, selfish manner.

The negotiation framework proposed in this work is aimed at providing the parties with incentives to advance from a distributive, rights- or power-based bargaining process to an integrative negotiation, which can converge to a solution beneficial to all parties involved. In order to move the riparians from adversarial positions towards win-win solutions, the interaction based on simple bargaining needs assistance by additional techniques and skills. The proposed Negotiation Support System (NSS), combines the tools of individual decision-making analysis, alternative dispute resolution (ADR) techniques, game theory models and some principles of free market theory. The model combines these approaches and tools, while relying on the notions of equity, fairness, efficiency, and stability.

The approach to model design is based on the conclusions drawn from a number of real-world cases of international water disputes. It recognizes the absence of mutual confidence between the parties, and assures a level of confidentiality in the manipulation of revealed information. Also, the approach does not assume that the agreement between the parties will be based on cooperation in management of the disputed and other water resources. It searches for the outcome that will be perceived as the 'best outcome' by both parties, given the level of their mutual trust and other negotiations conditions (“the state of the world”) at the time of the negotiations. If the outcome of a negotiation process supported by the model includes some of the elements of cooperation in water resources management, it is be because the parties select that alternative as the most preferred, according to their individual criteria.

The proposed negotiation framework incorporates ADR techniques, including joint analysis of the effects of proposed solutions, brainstorming, joint search for mutually preferred solutions, and techniques for solving the problems of fair division (game theoretic models). These techniques are used to decrease the effect of the power politics mechanism on the outcome, and increase both parties' feeling of equity and *fairness*.

This work brings into the negotiating arena the notion of *efficiency*, with a double meaning. In bargaining theory, the term “efficiency” is used to qualify the outcome of a bargaining process. A solution is considered efficient if it is not possible to move from it in a direction that increases the gain of both parties simultaneously. Moving from an efficient solution to increase the gain of one party, results in a decrease of the gain of the other party. Solutions that are efficient in the sense of the bargaining theory are referred to as Pareto Optimal or non-dominated solutions. A *rational* compromise solution must be chosen among the efficient solutions, since if the solution is not efficient it is possible to move from it in a way that improves the outcome for both parties. In regular (‘non-supported’) negotiations, it is up to the parties to use their cognitive skills to recognize and select an outcome from the set of efficient outcomes. However, the agreement concerning the outcome will depend also on the quality of communication and the level of mutual confidence between the parties. In a distributive bargaining, it may happen that the parties reach an agreement that "misses" some of the possible joint gains, and “leaves something on the table”, a solution that would make all of the parties of them better-off. The negotiation support model proposed in this work offers a game-theoretic algorithm which, given a set of feasible outcomes, selects those that satisfy the efficiency criterion.

An additional meaning of the notion of efficiency in this work is that of *economic efficiency,* which relate to the way water resources are utilized. Elements of water scarcity, which are at the basis of the disputes that are the subject of this thesis, are often related to an inefficient use of water at domestic and/or international level (see Section 1.1.7). Efficiency of water use is expressed by a system of prices at which consumers buy water, shadow prices of water, and supply costs. (see Section 3.3.1). The negotiation support framework includes a water-allocation optimization model, which enables an "on-line" analysis of the effects that each proposed (negotiated) solution has on the system of prices. According to the principles imbedded in the model, water resources are used in an efficient manner when the prices for consumers equal (or are close enough) to the sum of supply costs and the shadow value of water in the source.

Stability refers to a particular quality of the negotiated agreement. In bargaining theory, a stable solution of a bargaining problem is reached when the parties have no incentive to move away from that solution. This means that a selection of any other solution would represent a decrease in the level of satisfaction with the negotiated outcome. In resolution of disputes over international waters, the notion of stability is of extreme importance. A 'win-lose' outcome in such disputes is inherently not stable. If one of the parties leaves the negotiation table unsatisfied, there is a good chance it will break the agreement sometime in the future. Because of the concept of sovereignty, the lack of enforcement mechanisms, and the weakness of international law, the riparians still have the opportunity to deviate from the agreement. Only a 'win-win' outcome, which ensures a mutual benefit, can lay the foundation for a long-term resolution of the conflict.

The proposed Negotiation Support System supports the following processes:

1. *Structuring of the problem.*

The parties approach the negotiations with a basic aim to 'get as much as possible of the shared water resource'. However, the outcome of the negotiation process affects the parties (countries, entities) on both international and national levels. The proposed model forces the parties to 'break' that basic aim into a number of relevant domestic issues and goals (intensification of agricultural production, preservation of environmental quality, etc.) and international ones (improvement of the regional relationships, international reputation, etc.). This way, each party can, by himself, widen the scope of the allocation problem and analyze it from the different perspectives that are important for him. These perspectives are actually the criteria, according which the parties judge the quality of the offers that are "on the table". Two negotiating offers can be compared to each other in terms of a preference relation: a party either prefers one or the other, or is equally satisfied by both.

Within the set of criteria of a party, there is internal competition: the more an alternative satisfies some of them, the less it satisfies the others. Furthermore, a party attaches different importance to different criteria. Without a structure for analysis of his own decisions, a party may miss solutions that are “best” for him in a multi-criteria sense. It can happen, particularly in distributive bargaining, that the parties insist on mutually exclusive solutions until one of them, eventually, breaks the process. Structuring the problem as a multi-criteria decision process opens up the opportunity for 'individual' trade-off analysis and decision-making: giving up on one objective in order to gain more on another. From the perspective of a single party, an important component of the negotiation process is an individual multi-criteria decision-making procedure. The NSS includes a utility-theory-based individual decision support algorithm as an aid in the evaluation of utilities associated with possible negotiation outcomes.

2. *Analysis of the consequences of proposed negotiation solutions.*

Negotiation over allocation of shared waters are frequently conducted at the level of "rights", rights based on hydrological, geographical, historical, political or other right-related arguments. A typical negotiation process does not include an "on-line" (during the negotiation itself) analysis of how each riparian will actually use his share of the water resource, once it is determined. Within each country, water resources should be managed to satisfy defined objectives (economic, social, political, etc.) and with respect to_given constraints (water availability, capacity of the infrastructure, social constraints reflected in water policies, etc.). Management of a shared water resource that has been a subject to international negotiation is typically analyzed in a post-negotiation phase within each country separately. One of the assumptions of this thesis is that knowledge of the consequences of different intra-country management options for each proposed negotiation solution can add new perspectives in judging the "quality" of the offered alternatives. These new perspectives for analyzing different intra-country management scenarios during the negotiation process should help the negotiating parties be more creative in the search for mutually acceptable solutions. The negotiation framework proposed in this work includes a model which enables the negotiating parties explore, 'on-line', the effects of different negotiation alternatives on the water management objectives relevant for their countries. It is a water allocation optimization model, WAS (Fisher et al., 2002), which allocates annual quantities of available water to consumers so as to maximize the total net benefit from water utilization.

The model can be applied to a single country or to a region which covers the territory of two or more parties. The consumers are characterized in the model by their water demand curves – the functions that describe their willingness to pay for additional units of water. According to the basic principle of market theory, if two consumers assign different values to the same unit of any good, economic efficiency dictates allocation of that unit to the consumer which assigns it a higher value.

Real-world deficiencies of this principle in its application to water allocation (such as allocation of disproportionally large amounts of water to 'rich' countries or sectors within a country) are counteracted by a system of constraints. These constraints define, for example, the maximum or minimum quantity of water to be allocated to certain consumers, fixed prices or other pricing systems at which the consumers purchase water, governmental subsidies, etc. Other sets of constraints relate to the limitations of water supply and conveyance system, environmental considerations, like set-asides or penalties for certain water-uses, etc. The model includes the possibility of analyzing the justification for and effects of wastewater recycling, desalination of sea water, expansion of the conveyance system, or other modification of the physical system. Each negotiated alternative can be introduced into the model as a 'scenario' controlled by the system of constraints, and analyzed in terms of optimal quantities of water for allocation to consumers, and in terms of net benefit from water-use.

3. *Expanding the set of alternative solutions.*

Individual and group decision support models assist the users in dealing with their preferences over a known (offered), fixed set of feasible alternative solutions to the problem. It is not common for decision support system to provide assistance at the stage at which the alternatives are being created (Kersten, 1993). The ability of the users themselves to recognize or create "good" alternative solutions, directly affects their level of satisfaction with the final negotiation outcome. The water allocation optimization model used in this thesis provides the parties the opportunity to, individually or jointly, search for additional plausible solutions. Shadow values of the constraints within the WAS model (particularly, the shadow values of water itself) provide information about how much the objective function would change if a constraint were relaxed. Change in the constraints of the optimization model here means a change of the "scenario" (alternative solution) into a new one. New scenarios can be explored jointly by the parties. While brainstorming and negotiating "around" the WAS model, the parties have the opportunity to transform their roles of negotiators into the roles of (cooperative) problem solvers rather than merely opponents.

4. *Attitudinal transformation of the parties.*

Most decision theory models assume that the decision-maker's perception of a particular problem and system of values and preferences remain constant during the decision-making process. Experimental work (McNeal et al., 1988) indicates that an analysis of a decision-making problem from different angles, or change of its presentation, may invoke a change in the decision-maker's preference structure. This is what happens in a negotiation. According to Kersten (1993) there are problems that need to be continuously redefined and analyzed from different perspectives during the decision-making process. He argues that a decision support tool should be able to accommodate shifts in a decision-maker's preference structure or perception of the problem. The concept of shifts in preferences or attitudinal transformation of the parties has a central role in the proposed negotiation framework.

Negotiations over allocation of shared waters usually begin at the level of "rights", where emphasis is put on hydrological, geographical, historical, political and other right-related considerations. The parties approach the negotiations with a prepared strategy, which consists in merely pursuing their own self interests. The aim of the negotiation framework proposed herein is to enable the parties to "relax" the rights-related constraints and gradually direct their focus on a wider range of national and international issues that are actually affected by the water allocation problem. The negotiation support framework is aimed at providing the means for restructuring parties' goals and preferences, as well as of the alternative solutions.

5. *Selection of efficient and equitable solutions*:

The negotiation process reaches the stage at which there is a set of alternative solutions "on the table". Each of the parties has its preference structure over these alternatives already defined. When there is no single alternative judged as "the most preferred" by the both parties simultaneously, the problem is to agree and select one of the alternatives as final. For the parties, such selection involves making compromises and the question is how far should each of them compromise. A proper negotiation assistance should provide the parties with an unbiased means for aiding the selection of the final negotiated outcome. The proposed NSS offers an algorithm, based on the concepts of bargaining models from game theory, for the selection of the efficient and most equitable alternative solution from a set of feasible negotiated alternatives.

The approach to design of the proposed negotiation framework is based on the assumption that when parties are equipped with means that allow them to make projections and evaluate the outcomes of alternative proposals, they will improve their ability to resolve the conflict.

Chapter 2

Scope of the work

Negotiation processes are characterized by a number of elements/features. The role of each of these features in a particular negotiation process and its effect on the negotiation outcome depends on the specific negotiation situation. Design of a negotiation support model consists of: (a) identification of the important features of decision-making and negotiation that need to be captured and supported by the model, and (b) formal or informal modeling of the identified features. This chapter focuses on the first phase, and gives the justification for selection of the particular elements of decision-making and negotiations. The following chapter describes the approaches for the modeling of the selected elements.

2.1 Features of negotiation processes

Selection of the features of a negotiation process for the modeling, affects directly the applicability and efficiency of the support system. The basic features of a negotiation process that directly or indirectly influence the process and the outcome of negotiations, and can be captured by the model, include:

- <u>The symmetry of the parties in information and resources.</u> Parties are in a symmetric context when they both have the same information and resources (Gibbons, 1992). When this symmetry is broken, the relationship between the parties is often transformed substantially (Raiffa 1982) – the party that has more information and/or resources can have a larger influence on the outcome; the party is said to have more "power" (Corfman and Gupta, 1993).

- Time deadlines. When imposed on a negotiation process, time deadlines will have an effect the negotiation outcome.

- Interaction. Of all negotiation factors, quality of communication and interaction between the negotiating parties affects the quality of the outcome to the greatest extent. Organizing the interaction according to a set of normative (prescriptive) rules of public behavior (protocol of interaction), reduces the difficulties in communication. Generally, interaction is specified by two basic aspects: the *content* (the information that parties exchange with one another, and the *process* of interaction (when and how to interact).

- Strategies of interaction. A strategy is informally defined as an individually chosen action of a party given the rules of public behavior (Faratin, 2000). It is strategic because the party can have a number of choices of actions that will result in the achievement of a goal. This multiple choice of actions leads to parties having preferences and behaving strategically regarding which action to take.

- Rationality of the parties. The term rationality is informally defined as making appropriate decisions, or "doing the right thing" (Russel and Wefald, 1991). The rationality of a party is defined with respect to the negotiated issue and the origin of the party. For example, rationality of a cognitive party is defined in terms of what actions are legitimate given the party's current believes, desires and intentions (Bratman, 1987). The rationality of an economic party, on the other hand, is defined in terms of maximization of the party's preferences over states of the world (Gibbons, 1992; Binmore, 1992).

- Possibility of coalitions. In case of negotiations with more than two parties, some of the parties can combine their endeavors and resources and act against others as a single entity with common interests and goals.

- Monolithic interests. Generally, a negotiating party can represent several groups of people that do not share the same interests. Actions of this party during the negotiation process have to be agreed upon, or negotiated, internally, among all the influencing groups.

- Number of issues. Negotiation can be over one or more issues. In case of a multi-issue negotiation, the parties can consider each issue separately, or, they can negotiate a package of solutions supposed to address all issues simultaneously. Negotiation over a package of issues has an advantage over an issue-by-issue negotiation: in case the parties value the issues differently, they can trade the satisfaction achieved by less important (subjectively) issues, for greater satisfaction achieved by more valued ones.

- Available information: uncertainty and risk. Uncertainty arises because parties to negotiation seldom have full access to the entire information about the world. This lack of information can be due to a limited knowledge of the domain, or, a "procedural ignorance", which occurs when consequences of effects of actions are unknown (Russel and Norvig, 1995). Risk characterizes the attitude of the decision maker towards choices or, what is called lotteries, between a sure outcome and an expected outcome (Von Neumann and Morgenstern, 1944).

The scope of this work is defined by examining the elements of negotiations relevant for the subject of this work, which is international negotiation over shared waters. Section 2.2 presents the elements important from a multi-party perspective, while section 2.3 presents the elements relevant from a single party's perspective.

2.2 Multi-party issues

Number of parties. Just & Netanyahu (1998) state that the majority of international water treaties are between two countries. Bilateral agreements on water resource management occur even in basins with three or more riparian countries. They conclude that multi-lateral agreements can be reached only in an advanced state of multilateral coordination and it must be preceded by bilateral agreements. In view of the experience and conclusions drawn from real-world cases, this work is aimed at developing a negotiation support system (NSS) for negotiations between two riparian countries (or political entities). We believe that the principles embedded in the proposed negotiation framework could be applied also to multi-lateral negotiations. In this case, however, negotiation elements specific for multi-party situations, like the possibility of coalition formation, would have to be accounted for and adequately modeled.

Symmetry. Parties to negotiation over international waters can be characterized by asymmetry in various aspects (political power/influence in the region, level of expertise, capability of assessing information relevant for the negotiation process, etc.). In the proposed NSS, symmetry is accounted for by providing the same set of supporting tools to all parties and by applying a game-theoretic model of fair division as the criteria for selecting the most 'equitable' solution among a number of negotiated alternative solutions.

Rationality. As in any other real-life negotiation, parties of our concern cannot be considered *perfectly rational* in the economic sense (i.e. perfect maximizers of their individual preferences). We believe that actions of the parties involved in negotiations over international waters are driven by their beliefs and intentions (cognitive rationality). However, we assume that the assumption about the economic rationality can be applied for specific conditions, and we propose a mechanism for modeling a combination of cognitive and economic rationalities, as will be explained in the following Chapters.

Motivations. Parties negotiate in order to achieve certain goals. Interaction of individual motivations of parties to achieve their own goals directly influences the nature and outcome of negotiations. The importance of parties' motivations can be illustrated by an abstract game called the Prisoner's Dilemma (Figure 2.2.1). There are two players in this game and each has a choice of defecting or cooperating (Raiffa, 1982). Each player receives a payoff that expresses how good, in some subjective sense, the outcome is for the player. The sum of the payoffs shows how good the outcome is for the two of them as a *society*, or a *group*.

B / A	*Cooperate*	*Defect*
Cooperate	3,3	0,5
Defect	5,0	1,1

Table 2.2.1: The Prisoner's Dilemma Game

The payoffs for A and B, respectively, are shown as a pair of entries in each box. Suppose that the players are not allowed to communicate. The "dilemma" comes from the following: if both players cared for their joint welfare and decided to cooperate, they would achieve the highest *overall* payoff (3+3 = 6). However, if only one of them decided to defect, he would achieve the highest possible *individual* payoff (5). If both players acted in an economically rational manner and tried to maximize their individual payoffs, they would choose to defect, and their individual, as well as the joint payoff, would be the lowest (1+1 = 2). If the parties were allowed to communicate, they should rationally reach the joint decision to cooperate. This example explains the role of *motivation* in determining the parties' behavior.

As will be explained in the next chapter, there are two types of game theory models that simulate different types of parties' motivations. Cooperative models better describe the interaction between the parties who care about the joint welfare, while non-cooperative models are used in case the negotiators are self-oriented and pursue only their own interests.

Protocol of interaction. The protocol of interaction can be of various degrees of formality with respect to both process (when and how to communicate) and context (what to communicate). High-degree structured rules are appropriate in case the interactions are in danger of leading to chaotic dynamics (Faratin, 2000), when there is a risk that the parties will exchange inappropriate offers and arguments, or/and will not be able to find a mutually understandable way of communication. Such interactions are those amongst computational agents[1] (Faratin, 2000), or between extremely hostile human negotiators. In international negotiations over shared waters, the relationship between the parties is usually burdened by mutual mistrust and, often, hostilities. Such conditions are likely to exacerbate the communication between the parties, and prevent them from achieving mutually satisfying solutions, even when such exist. One of the assumptions of this work is that a structured protocol of interaction may assist the parties to overcome deadlock situations and advance towards an efficient negotiation outcome. The NSS includes a protocol of interaction, which guides the parties through the negotiation process. It is formal with respect to 1) *process*, since it prescribes sequential steps of individual and joint decision-making, and 2) *context*, since it requires a specified formulation of the

[1] Computational agents are software programs which represent interests of human agents (negotiators) in interactions with other computational agents (interactions such as buying and selling *via* the Internet).

proposed negotiation alternatives. The protocol is aimed at keeping the negotiating parties focused on efficient and productive elements of interaction. It is of a lower-degree formality, as it provides the parties with opportunities to argue and jointly brainstorm over the problem, as well as to be creative and practically unbounded in searching for alternative negotiation solutions.

2.3 Single-party issues

Individual preference system of a monolithic party. Our work assumes that in international negotiations over shared waters, the official negotiators are appointed by their respective governments to represent overall national interests and goals. Therefore, the NSS is designed to support negotiations between monolithic parties who represent unique systems of preferences. Internal negotiations within the parties are not within the scope of this work.

A negotiating party is characterized by it's individual preference system related to the negotiation problem. According to Kersten (1988), preferences evolve from the current understanding of the problem, and typically, are assumed to remain stable. He argues that in strategic decisions and negotiations, a continuous redefinition of the problem is required. The experimental work of McNeil, Pauker and Tversky (1988) indicates that re-evaluation of the problem, and even a change in the way it is presented, may activate new associations and invoke changes in the preference structure.

This work accepts suggestions regarding a *restructurable* modeling of the negotiation process and adopts the following assumptions: 1) a party's perspectives and preferences depend on the current alternative to a negotiation outcome (what would happen in case the negotiations are called off) and, 2) when provided with enough opportunities to re-evaluate their perception of the problem and re-structure their preferences, the negotiation parties are more likely to reach a mutually satisfying agreement. As will be presented in Chapter 4, the proposed negotiation framework supports an iterative format of negotiation, which enables formulation and reformulation of the problem, consideration of each decision alternative separately, understanding preferences over outcomes, and providing possibilities of evolving/changing perspectives.

Strategies. According to Pruitt and Rubin (1986) there are five basic negotiation strategies.

1. *Contending* is an attempt to resolve the conflict on one's own terms without regard for the other side's interests. It is one's effort to persuade others to agree to a solution that favors his own interests. This strategy has also been called *positional bargaining* (Fisher and Ury, 1981). Contentious strategies include tactics like threats and punishments, and they tend to yield poor outcomes. Contending may escalate the conflict. When outcomes are finally reached, they may be low-level compromises. Contention is often used as an opening negotiation strategy.

2. *Problem-solving* is an attempt to find mutually appealing solutions. Problem-solving tactics include: increasing available resources, compensation, exchanging concessions on low priority issues, minimizing the costs of concessions, and creating new mutually beneficial options. Mutually beneficial outcomes are more likely to last, to improve the relationship between the parties, and to benefit the wider society (Fisher & Ury, 1981). In order to reach such outcomes, the parties must be firm about their aspirations or goals, but flexible regarding the means used to reach those goals (Pruitt and Rubin, 1986). The risk of problem solving strategies is that they may backfire if the other side pursues a contentious strategy (as in the Prisoner's Dilemma Game).

3. *Yielding* is an attempt to reduce conflict by lowering one's aspirations.

4. *Inaction* is a strategy of keeping a 'low profile' and waiting for the other side to make a move.

5. *Withdrawing* is breaking off the negotiations.

Pruitt and Rubin (1986) also describe two approaches to modeling parties' choices of strategy:

1. *Dual concern model* views strategic choice as the product of two elements: concerns for one's own outcome and concern for the other side's outcome. When concern for both self and other is high, problem solving is a more likely strategic choice; a concern for

one's own outcome and low concern for the other leads to contending strategies. A low concern for oneself and high concern for the other, results in yielding strategies.

2. *Feasibility model* of strategic choice focuses on parties' assessments of the costs and effectiveness of the various strategies. According to this model, *problem-solving* strategies seem more feasible when there is a mutual trust between the parties, and when they perceive a common ground and availability of integrative alternatives. *Contending* seems more feasible to a party who has more power and the perceived costs of using contentious tactics are low. *Inaction* seems most feasible when there are no time constraints. A party selects to *break off* the negotiations when the expected benefit from the alternative negotiation outcome falls below his minimum aspiration.

In a typical distributive type of negotiations, the parties may have difficulties in assessing the feasibility of various strategies and tactics (because of bad communication, mistrust, etc.), and therefore are more likely to act according to the dual concern model. In a typical dispute over shared waters, the parties' level of concern for their own interests is very high while for those of the others, usually low. Such dual concern results in parties selecting contending strategies. One of the roles of the NSS is to assist (direct) the parties in acting in a more feasibility-like manner: first explore and assess the effects of various tactics (both contending and problem-solving) and then select the preferred strategy.

Quality of the solution. The quality of an outcome measures how good the outcome is from the perspective of either the individual or society (Binmore, 1992). Qualitative models often distinguish between zero-sum and non zero-sum games (Gibbons, 1992; Raiffa, 1982). *Zero-sum* games are defined as games where the sum of the individual payoffs for an outcome equals zero. A more formal explanation of zero-sum games is as follows: let I be the set of n players. Let S_i be the set of m_i individual strategies of player i, $S_i = s_1, \ldots, s_{mi}$, and S be the space of all possible joint strategies (combinations of individual strategies) of all players, $S = S_1 x \ldots x S_n$. Let $P_i(\sigma)$, be the payoff value for player i, resulting from joint strategy σ . Then, a zero sum game is defined as:

$$\forall \sigma \in S, \ \sum_{i=1}^{n} P_i(\sigma) = 0 \qquad (2.3.1)$$

where the payoffs always sum to zero. It follows that in a two player zero-sum game the interests of the parties are in conflict and self-interested parties will attempt to maximize their individual payoff.

There are *constant-sum* games, in which the parties' payoff always sum to a fixed constant *c* (Binmore, 1992). It can be shown that any constant-sum game can be changed into an equivalent zero-sum game by simply subtracting the constant *c* from all of one of the player's payoffs (Binmore, 1992).

In *non-zero (non-constant) sum* games, on the other hand, the interests of the players are not completely antagonistic. A non-zero sum game is defined as:

$$\exists \sigma, \sigma' \in S, \ \sum_{i=1}^{n} P_i(\sigma) \neq \sum_{i=1}^{n} P_i(\sigma') \qquad (2.3.2)$$

where at least one strategy combination is better from the view point of the group. This allows players to search for mutually more satisfactory outcomes. Such games are also called "win-win" bargaining (Raiffa, 1982).

As stated in Chapter 1, negotiations over international waters are typically perceived as zero-sum games. Since the main task of the NSS is assisting the parties in advancing from zero-sum to a "win-win" bargaining solution, modeling of negotiations has to include some objective measure of the quality of outcome. This measure will also serve as a benchmark in (empirically) analyzing the efficiency of the developed negotiation support framework.

Commitments. Since there is no international law or legal body that can force the parties to respect the agreement over a shared water resource, it is of crucial importance for the parties to reach an agreement to which they will have the incentive to commit. According to Binmore (1992), commitments are linked to the notion of trust and can be modeled correspondingly. For example, in cooperative domains, parties implicitly trust one another, since they know that they share a common goal and personal preferences can be overridden. Non-cooperative models of negotiation, on the other hand, implicitly model trust through a notion of *equilibrium* (as will be explained in the next Chapter), specifying a strategy for each agent where deviation from these strategies is individually irrational. Hence, in non-cooperative models, trust is self-enforcing.

Information. Information is an essential component of any decision making process. Young (1975) defines information as the knowledge about all those factors, both intrinsic and external to the decision maker, which affects the ability of an individual to make choices in any given situation. Even when there is no strategic interaction among a number of decision makers, the rational decision models identify the following information requirements for a decision maker:

- a set of alternative outcomes
- a set of preferences over outcomes
- an attitude towards uncertainty and risk

Most game theory models assume that the alternative outcomes are given a priori (Gibbons, 1992). This assumption excludes all decision making situations in which the range of alternative can be altered (by removing or adding alternatives). The need for modifying the set of the outcomes may occur because of a change in the available information, or due to a change of the set of the parties' objectives.

The second requirement is that the decision maker must have complete knowledge of his own preference structure regarding the problem. That is, he must be able to rank all the alternatives in terms of his preferences. Game theory assumes that these preferences are transitive and consistent over time (Gibbons, 1992). On the contrary, the assumption of this work is that the decision maker is allowed to change his perception of the problem during the decision making process (for example, because of new information) and, as a consequence, to change the elements and relations within his preference structure.

In negotiations over water resources, uncertainty arises mainly because of the following reasons:

- Due to the stochastic nature of hydrological processes, availability of water in disputed resources is subject to a random changes;

- Consequences of alternative outcomes are considered with respect to future demands for water, and these cannot be estimated with accuracy.
- The parties' knowledge of the problem domain is usually asymmetric and constrained, on one hand, by the level of their own expertise and resources, and, on the other, by general limitations in scientific and technological ability to know and understand all the aspects of the domain;
- Each party has limited information about other parties' interests, goals and preferences.

The current version of the WAS model does not account for the stochastic nature of water availability (the role of the WAS model in the NSS was explained in section 1.3; the full description of the model will be given in the next Chapter). It is assumed that an average annual renewable quantity of water can be estimated and agreed upon by the negotiating parties. Furthermore, the consequences of alternative solutions are described by the WAS output data. These data provide the basis for limiting the domain of negotiations to those aspects which comply with the assumption of certain information ("certain" meaning "completely known"). These are mainly the aspects that relate to within-countries water demand and water supply relations, physical connections between consumption districts and available water resources, and physical characteristics of the existing and/or planned water supply systems. Uncertainty related to these aspects can be accounted for by performing sensitivity analysis with the WAS model, based on various assumptions/estimates regarding future values of relevant input parameters.

The proposed NSS provides the parties the opportunities to interact, exchange information, learn each other's interests and needs, and gradually improve their mutual confidence. However, the model also accounts for the parties' need to keep some level of confidentiality: it employs decision support tools, which require complete information of both parties' preference structures, but can also be used individually, while keeping this information confidential.

One of the basic assumptions of this work is that the negotiating parties deal with various degrees of "uncertainty" regarding their individual system of preferences related to the water allocation problem. A significant part of the decision support within the NSS is dedicated to structuring of the negotiation problem into a set of individual negotiation objectives, as well as to a qualitative analysis and a quantitative representation of the parties' individual preferences over alternative negotiation solutions.

Chapter 3
Related Work

The next step in the design of the negotiation NSS is modeling the relevant components of the decision-making and negotiation processes explained in the previous chapter. *Negotiation analysis* has evolved from the studies on conflict resolution, mainly based on *decision analysis*. Decision analysis is concerned with representation and solution of decision problems. Decision problems arise when there is a need to resolve conflicts. *Individual decision-making* is a process in which a single decision maker has to select an action among a set of feasible actions (alternatives). Such process is complex when the decision maker has a number of conflicting objectives, and no single solution achieves “the best” for all objectives. *Group decision making* is situation in which a number of decision makers have to agree upon which course of action to take. If the power to decide is shared among two or more decision-makers, the decision needs to be negotiated. Kersten (1985) defines group decisions and negotiations as situations which engage two or more participants in two types of activities: communication and decision-making.

Decision making within a negotiation framework takes place at two levels: the individual level, where the parties have to resolve their own weights to be placed on different goals, and at a public level, at which separate, conflicting interests of the opponent parties are to be met. Beside conflicts, negotiation processes are characterized by interdependency of the parties: realization of one party’s objectives depends on the others, and conversely, each party can influence the final decision. *Game theory* extends decision theory to situations where decision-making and actions are strategically interdependent, that is, where outcomes of one player's decisions are dependent upon the decisions of others and *vice versa*.

Neither decision theory nor game theory are concerned with designing the alternative solutions: in both theories, these are usually considered given externally, or determined *a priori* (Kersten, 1988). Our proposed negotiation framework includes the Water Allocation System (WAS, Fisher et al., 2002) as the model for generating, evaluating, and assessing physical (water allocations and flows within each country) and economic consequences of alternative negotiation solutions.

The first two sections of the chapter (3.1 and 3.2) give a review of the approaches and methods of decision analysis and game theory. Section 3.3 presents the Water Allocation System (WAS) adopted in the thesis for the modeling of the economically optimal allocation of water resources.

3.1. Decision analysis

Techniques of decision analysis can be applied to different situations to help represent, analyze and solve decision problems (Keeney and Raiffa, 1976). Individual decision support techniques differ in the way they account for the available information about the consequences of alternative decisions (such as costs and benefits), risks, and the decision-maker's preferences. With respect to the type of information about the consequences, Luce and Raiffa (1989) classify decision-making conditions in the following way: conditions of *certainty*, in which every course of action has one and only one consequence, and a choice among alternatives is equivalent to a choice among consequences; conditions of *risk*, in which each course of action will have one of several possible consequences, and the probability of occurrence of each consequence is known; the probability distributions of the consequences are unknown, and the decision-maker has to make a choice under *uncertainty*.

Techniques for assisting individual decision-making assume that the solution to a decision-making problem should be consistent with the decision-maker's system of preferences. They are about transforming the decision-maker's needs and values into specific objectives, aspirations and goals, and about introducing these into models of decision (Kersten, 1988).

There are two basic approaches to decision making analysis and support. The first is concerned with development and application of *normative (prescriptive)* decision rules, which prescribe the actions that the decision-maker should take in order to achieve an optimal solution. Normative rules are based on the assumption of decision-makers perfect rationality (see Chapter 2 for definition of rationality). The most common approach to normative analysis for conditions of *certainty* is based on multi-attribute utility (MAU) theory, which prescribes obtaining a utility value for each decision alternative and then selecting the alternative with the highest value. "Multi-attribute" means that the utility of an alternative is the weighted sum of separate utilities for the decision-maker's objectives (Gardiner and Edwards, 1975). As aids under conditions of *uncertainty*, models like decision trees, which display the sequence of decisions and outcomes are used. For each sequence, an expected utility is computed, based on known probability distributions of all possible outcomes (Raiffa, 1968).

The second approach to decision analysis evolved from the observed discrepancies between normative rules and actual behavior (Kersten, 1988). It involves *descriptive* techniques, which account for the way people actually make judgments and choices. Edwards (1954) substitutes *subjective probabilities* for *objective probabilities* and psychological utilities for payoff amounts to produce *subjectively expected utility* (SEU). According to Tversky and Kahnemann (1974) decisions are often made using psychological shortcuts or 'heuristics': determining probabilities based on the similarity of an event to an underlying cause or source of the outcome. This approach has been used to account for sub-optimal decisions in accounting, management, and marketing.

For reasons explained in Chapter 2, we concentrate on individual decision-making support under conditions of certainty, whose basic principles are given in the following.

3.1.1 Multi-objective decision analysis

Multi-objective decision-making analysis (MODM) is concerned with problems in which the decision maker deals with a number of competing or conflicting objectives. Objectives (or *decision criteria*) are statements of something that one desires to achieve (Keeney and Raiffa, 1976). Objectives are conflicting when achieving more of one objective decreases achievement of others. Usually there is no single solution that is better than all others with respect to all objectives, and the decision-making problem becomes one of tradeoffs. The decision-maker has to decide how much he is willing to give up on the achievement of one objective in order to improve the achievement on the others. A value tradeoff problem can be solved in two ways: the decision-maker can analyze, informally, in his mind, the importance of the objectives and the suitability of the alternative solutions to the problem, or, he can explicitly formalize his value structure within a framework that will guide him in the evaluation of the alternatives (Keeney and Raiffa, 1976). Multi-objective decision-making (MODM) theory deals with methods for formal evaluation of individual value structures. Application of the principles of MODM theory to the design of the proposed negotiation support system (NSS), is conditioned by the assumption that each negotiating party (country, entity) is represented by a single decision-maker, or a group of representatives that, in front of the opponent party, act as a single decision maker.

3.1.2 Mathematical formulation of a MODM problem

Decision objectives are measured in terms of attributes. Attribute $\boldsymbol{X(a) = x}$ indicates the level to which objective $\boldsymbol{O}$ is achieved by alternative $\boldsymbol{a}$. For example, in a domestic water allocation problem, the annual quantity of water supplied to agricultural consumers can measure how the objective *intensification of agricultural production* is achieved.

Outcomes of an attribute are referred to as *performance levels*. When a performance level is associated with a certain alternative the term *consequence* is used instead.

A multi-objective decision making problem can be defined as follows:

Let act ***a*** be a solution to the problem in the feasible space ***A*** ($\boldsymbol{a} \in \boldsymbol{A}$). $\boldsymbol{X_1(a),...,X_n(a)}$ are ***n*** attributes which map alternative ***a*** from ***A*** into an ***n***-dimensional *consequence* space ***C***. Within the consequence space, act ***a*** is represented by the vector $\boldsymbol{(x_1, \ldots, x_n)}$ where $\boldsymbol{x_i = X_i(a)}$, $\forall\, \boldsymbol{i}$. A graphical representation for a three-dimensional consequence space (three attributes) is shown in Figure 3.1.1.

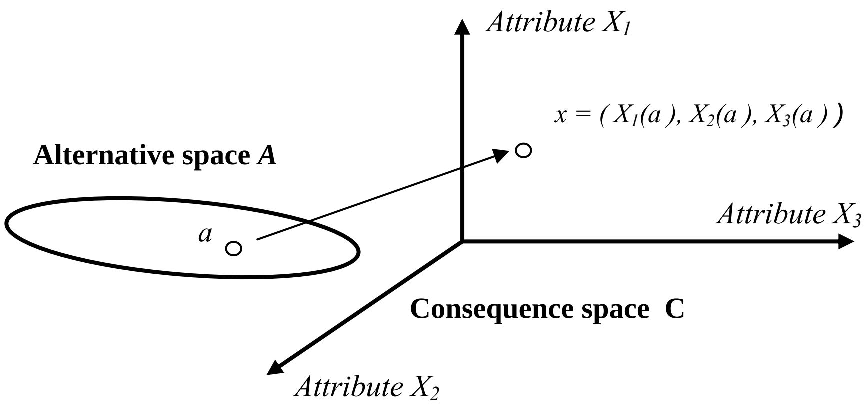

Figure 3.1.1: Alternative space and a three-dimensional consequence (attribute) space (*Keeney and Raiffa*, 1976).

The decision maker's problem is to select an ***a*** in ***A*** so as to maximize his satisfaction with the consequence $\boldsymbol{X(a)} = (\boldsymbol{x}_1, ..., \boldsymbol{x}_n)$.

3.1.3 Dominance relation

Two alternatives in *alternative space* $\boldsymbol{A}$, are compared according to their consequences in the *consequence space,* $\boldsymbol{C}$. If $\boldsymbol{x}'$ and $\boldsymbol{x}''$ denote vectors of consequences of alternatives $\boldsymbol{a}'$ and $\boldsymbol{a}''$, respectively, then, the *dominance* relation can be formulated as:

$\boldsymbol{x}'$ dominates $\boldsymbol{x}''$ whenever: a) $x_i' \geq x_i'', \ \forall i, \ and,$

b) $x_i' > x_i'', \ \exists i.$

Consequence $\boldsymbol{x}'$ dominates consequence $\boldsymbol{x}''$ whenever it is as good as $\boldsymbol{x}''$ with respect to all attributes, and strictly better than $\boldsymbol{x}''$ for at least one attribute. If $\boldsymbol{x}'$ dominates $\boldsymbol{x}''$, then $\boldsymbol{a}''$ is not a candidate for "the best alternative".

3.1.4 Choice of *the best* alternative

There are two approaches for selection of the best alternative. In the first, the alternatives are directly compared in terms of their consequences (informal analysis, Kenney and Raiffa, 1976). In the second, the preference structure over $\boldsymbol{C}$ is first formalized and the decision-making problem is solved by finding a point in $\boldsymbol{C}$ that yields the greatest preference according to this structure.

3.1.4.1 Informal analysis

Some procedures of the first approach propose searching for the alternative which satisfies some or all aspiration levels $x_1^o, x_2^o, \ldots, x_n^o$, selected for the $\boldsymbol{n}$ attributes. This is done in an iterative manner, by increasing the aspiration levels (to reach non-dominated alternatives) or decreasing the aspiration levels (to find feasible alternatives). Another procedure searches for alternatives which maximize one attribute, for given aspiration levels of other attributes, or, the alternatives which maximize the sum $\sum_{i=1}^{n} \lambda_i X_i(a)$, where $\lambda_i > 0, i = 1,..,n$ are the weights of the importance of each attribute such that $\sum_i \lambda_i = 1$. All procedures for exploring the efficient frontier are performed iteratively, where in each iteration the decision-maker has to manipulate the aspiration levels, x^o, or, multipliers λ, and to balance, informally, what he would like to get and what he is ready to give up (reference).

3.1.4.2 Formal structuring of preferences

A preference structure is defined on a consequence space if any two points are comparable and no intransitivity exists. The assumption is that the decision-maker believes that in a specified decision context there is a particular preference structure that is appropriate for him (Keeney and Raiffa, 1976). In this case, the problem is formalized as:

find $a^0 \in A$ so that $X(a^0) \succeq X(a), \quad \forall a \in A$,

where $X(a) = [x_1(a), x_2(a), \ldots, x_n(a)]$,

or, find $x^0 \in C$ such that $x^0 \succeq x, \quad \forall x \in C$

For a formal analysis, comparison of consequences of different alternatives requires specification of a scalar function ***v*** defined on the consequence space ***C***, with the following property: if the consequences for two distinct acts, a' and a'', are $X(a') = (x'_1,..,x'_n)$ and $X(a'') = (x''_1,..,x''_n)$, then:

$$v(x'_1, x'_2, \ldots, x'_n) \geq v(x''_1, x''_2, \ldots, x''_n) \Leftrightarrow (x'_1, x'_2, \ldots, x'_n) \succeq (x''_1, x''_2, \ldots, x''_n)$$

where $\succeq$ means "preferred or indifferent to". Any function with such property is called a *value function* (preference function, utility function). It assigns to each object a value so that the object with a greater value is preferred to objects with lower values. *Ordinal* value functions capture only the preference *order* of alternatives, while *cardinal* value functions provide also the *strength* of the preferences.

Examples of cardinal value functions for $n = 2$ are:

$$v(x) = c_1 x_1 + c_2 x_2 \qquad c_{1,2} > 0$$
$$v(x) = x_1^{\alpha} x_2^{\beta} \qquad \alpha, \beta > 0$$
$$v(x) = c_1 x_1 + c_2 x_2 + c_3 (x_1 - b_1)^{\alpha} (x_2 - b_2)^{\beta}$$

With a defined value function, the decision maker's problem is a standard optimization problem: find $\boldsymbol{a \in A}$ that maximizes ***v(x)***.

Selecting an appropriate shape of the value function to adequately represent the decision-maker's preference structure over a defined consequence space is of crucial importance in a formalized decision-making problem. Keeney and Raiffa (1976) have shown that, in many circumstances, a linear additive model:

$$v(x) = \sum_{j=1}^{n} w_j x_j = w_1 x_1 + w_2 x_2 + \ldots + w_n x_n$$

where w_j is the relative importance of attribute j, $j = 1,\ldots,n$ and x_j is the value of attribute j assigned to alternative x, can be a robust and straightforward approximation to the SEU concept (*subjective expected utility*, see section 3.1). They showed that this model can be used to resolve the difference between how decision makers *should* make *rational decisions* and how they *actually make judgments*.

In our work, we adopt the linear additive model for structuring of individual systems of preferences. The methodology selected for deriving subjective linear value functions is described in the next section.

3.1.5 The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-objective decision-making approach introduced by Saaty (1988). The AHP is a method for individual structuring, presentation and evaluation of a multi-objective decision problem. It is designed to select the best from a number of alternatives evaluated with respect to several objectives (criteria). The method is based on the concepts of decomposition and synthesis: first, the decision-making problem is defined, its complexity is decomposed into simpler elements; then the relationships among the elements are recognized and synthesized to identify the best solution to the problem. The problem is decomposed in a hierarchical structure to study the functional interactions of its components and their impacts on the overall decision goal (Figure 3.1.2).

This aspect of the AHP is no less important than the process of obtaining the preference structure by giving weights. Structuring the problem, in terms of a hierarchy with clearly defined positions and relations between the elements, forces the decision maker to clarify – for himself and for others – his perception of the decision making problem. In the context of any decision making situation, and in particular in the NSS (where two sides are interacting iteratively) the structure itself is likely to change as new information is revealed, and the negotiation procedure proceeds. Also, during the iterative process, the weights can (and usually will) change.

For assessing the relationship (relative importance) among the elements of the structure, the AHP utilizes the assumption that human decision makers make good judgments for small groups of objects. It prescribes pair-wise comparisons which are used to develop overall priorities for ranking of the decision alternatives.

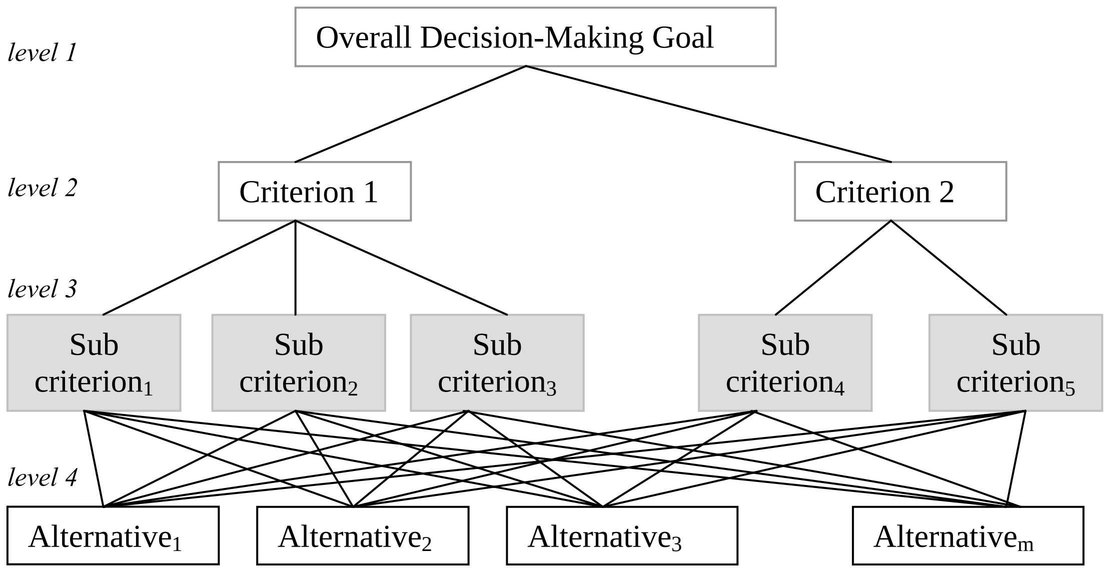

Figure 3.1.2: Hierarchical presentation of a decision-making problem

3.1.5.1 Methodology and mathematical background

The Analytic Hierarchy Process (AHP) is based on pair-wise comparisons and the use of ratio scales in preference judgments.

Let $\boldsymbol{C_1,\dots,C_n}$ be the elements of level $\boldsymbol{l}$ in a hierarchy, for which a decision-maker (DM) wishes to find the weights of importance, $\boldsymbol{w_1,\dots,w_n}$, with respect to a particular element in level ***l-1***. The AHP method requires the DM's subjective estimation of the ratios of the elements' weights:

$$r_{ij} = \frac{w_i}{w_j} \quad i, j = 1,...,n \tag{3.1.1}$$

where $\boldsymbol{r_{ij}}$ are numerical values associated with verbal statements, as given in Table 3.1.1.

Table 3.1.1: The AHP comparison scale

Verbal statement	Scale
Equally important	1
-	2
Slightly more important	3
-	4
Strongly more important	5
-	6
Very strongly more important	7
-	8
Extremely more important	9

The results of paired comparisons are the entries of the *comparison matrix, **A**:*

$$A = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nn} \end{bmatrix}$$

A comparison matrix is (or should be, see below) a positive reciprocal matrix, in which the elements of the diagonal, $\boldsymbol{r_{ii}}$, are 1 (an element compared to itself). In practice, the decision-maker is sometimes asked to estimate only the entries of the upper triangular matrix, and it is assumed that:

$$r_{ji} = \frac{1}{r_{ij}}. \tag{3.1.2}$$

The weights of the relative importance of the elements, $\boldsymbol{w_1,\dots,w_n}$, are obtained from the matrix A, by a calculation procedure, based on the following:

If the decision-maker were perfectly consistent in his estimation, the following would be true:

$$r_{ij} r_{jk} = \frac{w_i}{w_j} \frac{w_j}{w_k} = \frac{w_j}{w_k} = r_{ik}, \;\; \forall\, i, j, k \in \{1,...,n\} \tag{3.1.3}$$

For a perfectly consistent matrix of comparisons (A), the following holds:

$$r_{ij} \cdot \frac{w_j}{w_i} = 1, \qquad i, j = 1,...,n$$

$$\sum_{j=1}^{n} r_{ij} w_j \cdot \frac{1}{w_i} = n, \qquad i = 1,...,n \text{, or}$$

$$\sum_{j=1}^{n} r_{ij} w_j = n \cdot w_i, \qquad i = 1,...,n. \qquad (3.1.4)$$

In matrix form, the last expression is equivalent to:

$$\underline{\underline{A}}\,\underline{w} = n\underline{w}\text{, or, } A = \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} \qquad (3.1.5)$$

which means that ***w***, the vector of weights, is an eigenvector of ***A*** with eigenvalue ***n***. Since it is desirable to have a normalized solution, the components of $\underline{\boldsymbol{w}}$ are normalized to $\sum_{i=1}^{n} w_i = 1$.

Such pair-wise comparisons and calculations are performed, and the vectors of weights are obtained for all the elements and all the levels of the hierarchy (except for the single element of the uppermost level). In order to obtain the overall weights of importance of the alternatives, which are the lowest level of the hierarchy, the following steps are applied:

- for each level ***l*** (except for the uppermost): ***l = 2,…,m***, where ***m*** is the number of the levels in the hierarchy, a $\boldsymbol{n_l \times n_{l-1}}$ matrix is composed of column-vectors of weights, $\underline{\boldsymbol{w_j}}$, $\boldsymbol{j=1,\ldots n_{l-1}}$, where $\boldsymbol{n_l}$ and $\boldsymbol{n_{l-1}}$ are the numbers of elements in levels ***l*** and ***l-1***, respectively;
- the final composite vector of weights of the alternatives is obtained by multiplying the matrices of all layers:

$$\underline{w}_{final} = M_m \cdot M_{m-1} \cdots M_2. \qquad (3.1.6)$$

$\underline{w}_{final}$ can be perceived as a measure of the decision-maker's overall satisfaction by the decision alternatives. In this case, equation 3.1.6 is actually an additive linear utility function. As example, for a three-levels hierarchy (a hierarchy with a global objective, a single level of specific objectives, and a level of alternatives), the final composite vector of weights is obtained as:

$$\underline{w}_{final} = M_3 M_2 =$$

$$= \begin{bmatrix} w_1(a_1) & \cdots & w_p(a_1) \\ \vdots & \ddots & \vdots \\ w_1(a_q) & \cdots & w_p(a_q) \end{bmatrix} \begin{bmatrix} w_{o1} & \cdots & w_{op} \end{bmatrix} = \begin{bmatrix} w_{o1}w_1(a_1)+ & \cdots & +w_{op}w_p(a_1) \\ \vdots & & \vdots \\ w_{o1}w_1(a_q)+ & \cdots & +w_{op}w_p(a_q) \end{bmatrix}$$

where $w_{o1},\ldots,w_{op}$ are the relative importance of the objectives, and $w_i(a_j)$, $i = 1,\ldots,p$, $j = 1,\ldots,q$ is the weight of decision alternative a_j with respect to objective o_i.

3.1.5.2 Measuring subjective inconsistency

Entries of a comparison matrix, r_{ij} are subjective judgments, and they most probably deviate from perfect consistency. That is, for n weights, the decision maker gives $n(n-1)$ estimates and the following might be true: $\exists\ i,j,k \in \{1,\ldots,n\}$ such that $w_{ij}w_{jk} \neq w_{ik}$.

By applying laws of matrix theory, it can be shown that in case of a positive reciprocal matrix of size $n \times n$, all eigenvalues are zero, except one, which is n. Furthermore, if the entries a_{ij} of this matrix are changed by small amounts, then the eigenvalues change by small amounts as well. Hence, if the entries of a comparison matrix deviate from perfect consistency by small amounts, its largest eigenvalue is still close to n and the remaining eigenvalues are close to zero. This fact is used to calculate the consistency index of a comparison matrix as:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3.1.7}$$

where λ_{max} is the largest eigenvalue of the comparison matrix of size ***n x n***. In general, if this number is less than 0.1, the subjective judgments represented by the entries are considered consistent.

3.1.5.3 The AHP method for individual decision support in a negotiation process

In the context of this study, we found that the AHP method can help parties in understanding their own perception of the water allocation problem. The method enables detailed structuring of the negotiating problem into relevant components, and allows dynamic changes as the negotiation proceeds: adding and removing elements from a hierarchy is easy and requires simple subjective input as well as easy computing to update the weights of the elements in the changed structure. Even though there are other approaches to individual decision support (like value trees, Dodgson et al., 2000), which could be equally suitable as a component of a negotiation support framework, we selected the AHP as the method that has been proven as convenient and widely acceptable by individual decision-makers (*Saaty*, 1980, Shamir et al., 1985).

3.2 Concepts and aims of game theory

Game Theory started as applied mathematics and has become a dominant way of reasoning in business and macro and microeconomics (Binmore, 1992). A game is being played whenever people interact with each other. Competing in business, economics and various forms of bargaining, negotiation, and arbitration are interactions which have some common features that bring them all under the category of games. In such interactions there are interacting *players* (agents, parties) whose behavior is governed by *rules* that define what each of the players can do. A player is viewed as an individual actor even though this term can stand for a company, nation or any other group of actors who act as a single decision-maker. According to his believes or knowledge about other player's *actions*, each player selects *strategies* aimed at achieving the goal of the game. Strategies of the opposite players in a game are interdependent. The quality of the strategies and strategic interdependence affect the *outcome* of the game. The outcome of a game is described by a *payoff* to each player. Gardner (1995) combined these features in a definition of a game as “any rule-governed situation with a well-defined outcome, characterized by strategic interdependence”.

Game theory makes simplifying assumptions to facilitate mathematical analysis. The two common assumptions are: (1) complete knowledge of the circumstances in which the game is played and (2) full rationality of the players. The first assumption implies that the rules of the game, the outcomes, and the preferences and beliefs of the players are “common knowledge”. The second assumption refers to how players reason: a player is assumed to act to achieve the best payoff for himself. He is described as a maximizer of a specific function, which, in that particular game, reflects his own satisfaction with the outcome (Binmore, 1990). This function is called the utility or payoff function. The objective of game theoretic models is to analyze what are the players' best choices, given a set of possible moves.

3.2.1 Game theoretic approaches to bargaining

Since the concern of this work is negotiation between two parties, the class of game theoretical models of particular interest is bargaining models. These are derived from the economic models of game theory, whose basic concern is a rational allocation of scarce resources through coordination mechanisms such as markets and bargaining (Binmore and Dasgupta, 1989). Macro-economic models focus on perfect competition explained through markets, while micro-economic models focus on individual bargaining in situations of imperfect competition (Gibbons, 1992).

Bargaining interaction can be analyzed from two perspectives. One perspective assumes that the players mistrust one another and try to maximize their own benefit irrespective of others (see Chapter 2 for the Prisoner’s Dilemma game). The other perspective assumes that the players make binding agreements to coordinate their actions (strategies). The first perspective, modeled by non-cooperative games, focuses on *process*, while the second perspective, modeled by cooperative games, focus on the *outcome* of a game.

3.2.2 The Theory of Cooperative Games

Cooperative game theory considers the space of possible outcomes of a game, without specifying the game itself in detail. In bargaining, the outcomes are often denoted in terms of utilities (Binmore, 1992). In case of two-player games, the outcomes are represented by utility pairs. Cooperative bargaining theory is concerned with the question of which outcome will eventually prevail, given the set of all possible utility pairs. A particular set of possible outcomes is also referred to as a *bargaining problem*. A function which maps a bargaining problem to a single outcome is called a *solution concept*. A solution concept is characterized by the set of axioms which reflect the desirable properties of the solution (Gibbons, 1992). In such situations, there are two players who have to negotiate a solution $o \in O$, where O is the set of feasible solutions. If they reach an agreement, then they each receive a payoff defined by their utility function. A utility function U_i represents the preference relation $\succeq$ of a player i ($i = 1,2$) over the set of outcomes O (Binmore, 1992). If they fail to reach an agreement, they receive the conflict payoff, $U_i(conflict)$. Conflict payoff, or the reservation value, represents the minimum acceptable value that the party expects to get from the bargaining. Reservation value derives from what alternatives are open to the party in case of no agreement. It is the standard against which any bargaining (negotiation) solution is measured, and is referred to as the BATNA (the Best Alternative to Negotiation Agreement, Fisher and Ury, 1981).

The set of possible outcomes and the conflict point c is shown in Figure 3.2.1. Assuming that both parties behave in a rational manner, the solution to a bargaining problem satisfies the following: it is not worse than the conflict point, and there is no other agreement that both parties would prefer.

In every bargaining game, the set of feasible outcomes (O) is bounded by the Pareto Optimal line. Pareto optimality is defined for a bargaining game (O, c) as follows: let o_1 and o_2, be two outcomes from the set of feasible outcomes, $o_1, o_2 \in O$. If $U_i(o_2) > U_i(o_1)$ for $i = 1,2$, then the negotiators will agree on o_2. Actually, they will never agree on an outcome that can be improved, from the perspective of at least one of them, by another feasible outcome. The assumption here is that the players must be able to know and communicate that o_2 is better than o_1. All the outcomes that cannot be improved from the perspective of both players lie on the Pareto or Efficiency Frontier.

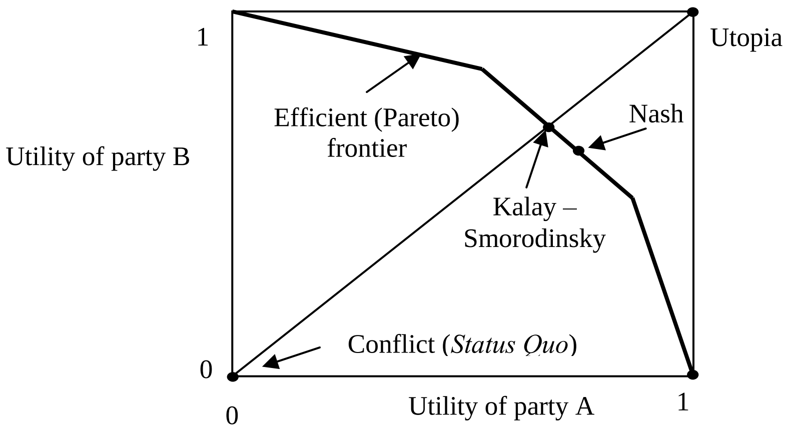

Figure 3.2.1: Utility (payoff) space for two bargaining parties and proposed "optimal" bargaining solutions.

The aim of cooperative theories is to specify axioms that lead to the selection of a single point on the Pareto frontier, given the bargaining problem ***(O, c)***. The most popular solution concept is the Nash bargaining solution, which requires the following axioms to be satisfied (Nash, 1950):

- *Invariance under affine transformation*. A change in the scale of the utility function does not change the outcome, only the numbers associated with the outcomes. This axiom is used to prevent the need to make interparty comparisons in utility, since negotiators may want or need to transform their utility functions to convenient scales. For example, if one party has $20 in the bank, and evaluates the deal that gives him $x as having a utility 20 + x, while another party evaluates such a deal as having x, it should not influence the Nash solution. That is, the change of origin does not affect the solution.
- *Symmetry (the anonymity axiom)*. This states that only the utilities associated with feasible outcomes and the conflict outcome determine the final outcome. No other information is required to select the preferred outcome, and switching the labels of parties does not affect the outcome.
- *Independence of irrelevant outcomes.* It states that if some outcomes *o* are removed, but the solution, *o*,* is not, then *o** is still the solution.
- *Pareto efficiency.* As mentioned above, this axiom refers to the maximum amount of utility that can be reached. This is the maximum possible amount

and not a complete aspiration achievement by both parties (the point denoted as "Utopia" in Figure 3.2.1).

The unique solution that satisfies the above axioms is the Nash solution, defined as:

$$o^* = \arg\max_{o} [U_1(o) - U_1(c)][U_2(o) - U_2(c)] \qquad (3.2.1)$$

This is the point which maximizes the product of individual utilities, relative to the conflict payoff, ***c*** (Nash, 1950). The multiplicative form of the Nash solution represents the concern for equity – the product of the value gains is maximized for more *equal* individual gains (Binmore, 1992).

Another solution to a bargaining problem is the *reference point.* This solution is observed in experimental bargaining problems where a prominent outcome is used by negotiators to anchor a point in the set of outcomes ***O*** (Raiffa, 1982). The negotiators can then use this anchorage/reference point which they may attempt to jointly improve. This point can be used either as a commonly agreed upon starting point, or a credible final point (Roth, 1985).

Kalai-Smorodinski solution is a point that lies on the Pareto frontier where it intersects with a line that connects the conflict point with the maximum achievement of each party's aspiration levels ("Utopia"). This solution is different from the Nash solution in fact that, instead of the *independence of irrelevant solutions*, it satisfies the *monotonicity* axiom, which implies that an expansion of the feasible set ***O*** in a direction favorable to a particular party, always benefits him. The two solutions may coincide, depending on the shape of the Pareto frontier.

Thus, cooperative game theory provides a number of criteria for selecting a solution from a given set of bargaining solutions. The choice of a specific solution is based on which axioms are reasonable in a specific bargaining context (Gerding et. al, 2000). Beside the fact that in order to apply a particular solution concept, the parties would have to agree upon the same set of "reasonable" axioms, another obvious precondition for any cooperative solution concept is the availability of relevant information. For example, to compute the reference point or outcomes that actually lie on the Pareto-optimal line, the parties have to know the utilities the other party places on all the outcomes.

3.2.2.1 Side payments

A game in which there is a mechanism to transfer the utilities from one player to another (for example, in case they measure utilities in the same units), is called a transferable utility game (TU, as opposed to non-transferable utility games, NTU). In such a game, the players can make *side payments* of utility as part of the agreement. By adding a side payment, payoff values for a bargaining outcome o, $(u_1(o), u_2(o))$, can be changed to $(u_1(o) + s, u_2(o) - s)$. If s is positive, it represents a payment from Player 2 to Player 1 (and *vice versa*). Side payments enable the parties to enlarge the set of feasible solutions and compensate each other for less satisfying outcomes.

3.2.3 Non-cooperative game theory

Non-cooperative game theory is concerned with specific games which have a well defined set of rules and game strategies. In order to be well-defined, a game must specify:

- the set of players;
- sequence of decisions;
- a precise structure of the information flow;
- the players' preferences over the set of all possible outcomes of the game.

A game must also specify what each player can do and when he can do it, and indicate who gets how much when the game is over. The structure used to present such information in game theory is called a tree (Binmore, 1992). Each node of a tree, other than a terminal node, determines a sub-game. The rules of the game and all possible strategies are known by the players, prior to the game.

Non-cooperative game theory uses the notion of an *equilibrium strategy* to determine "rational" outcomes of a game. Most commonly used concepts are dominant strategy, Nash equilibrium and sub-game perfect equilibrium. A *dominant strategy* is optimal in all circumstances, no matter what the strategies of the other players are. The strategies of all players are said to be in *Nash equilibrium*, if no player can benefit by unilaterally changing his strategy. In *sub-game perfect equilibrium*, the strategies for each sub-game of the game tree constitutes a Nash equilibrium (Gerding et al., 2000).

There are different protocols that can be used by two bargainers to divide a given quantity of bargaining goods. Some of them are:

1. *The Nash demand game*. Both players simultaneously demand a certain fraction of the goods, without knowledge about the other's demand. In case the sum of demand exceeds the total amount available, there is no agreement (both players receive their disagreement payoff). Otherwise, the demands are said to be compatible, and both players get what they requested. This game has an infinite number of Nash equilibria: all agreements which are Pareto-efficient, and also "disagreement" outcomes: if both players ask for more than the whole amount of the goods, no player could ever gain by unilaterally changing his strategy.
2. *The ultimatum game*. In this game, one of the players proposes a split of the goods and the other player has only two options: accept or reject. In case he rejects the offer both players get nothing. The game has an infinite number of Nash equilibria, and only one sub-game perfect equilibrium, where the first player demands the whole quantity of the goods, and the second player accepts it.
3. *The alternating-offers protocol*. This is a multiple-stage version of the ultimatum game: one player starts by offering a fraction x of the bargaining goods. If the other player accepts the offer, he receives x and the first player receives Q-x (where Q is the total amount available). Otherwise, the second player has to make a counter offer in the next round, which the first player can accept or reject. This process is repeated until one of the players agrees or until a finite time-deadline is reached. Several authors have developed solutions to this game, each true for some underlying assumptions: Stahl (1972) had a solution for a game of finite length in which the players were forbidden to increase their demands during the play; Rubinstein (1982) used the assumption that the player's preferences over the outcomes are time-invariant; Van Damme et al. (1990) analyzed a variant of the game with a finite number of alternatives (defined by a smallest unit of division of the good), etc.
4. *Monotonic concession protocol* is a more restricted protocol than that of the alternating-offers game: the two players announce their proposal simultaneously. If

the offers match or exceed the other player's demand, an agreement is reached. If no agreement is reached, the players have to make new offers in the next round. They are only allowed to concede or make the same offer as in the previous round. Because in each round at least one of the players has to make a concession (or disagreement occurs), the protocol has a finite execution time if a minimum concession per round is fixed and is larger than zero (Gerding et al., 2000).

Protocols of strategic games require complete information about the players' preference functions. For example, in order to make a concession, a player needs to have some information about the other players' preferences. This knowledge is crucial when the values the players put on various outcomes of the game are derived by multi-attribute utility functions (see section 3.1), meaning that each player has a set of differently valued attributes (negotiation objectives).

3.2.4 Applicability of game theoretic models of bargaining to real-life situations

In real-life negotiations, private information such as reservation values (i.e. minimum acceptable payoffs or BATNAs), preferences over outcomes, attitudes towards risk, etc., are often kept confidential, and the assumption about common knowledge regarding the preferences and beliefs of the players (see section 3.2) cannot be applied. There are game theoretic approaches to modeling optimal behavior of rational players given the fact that they have incomplete information about the world. Harsanyi (1967) proposed models which represent characteristics of players, status of information about the game, information about the opponents etc., considering the various types of person a player can belong to. Such models assume that the distribution of types is common knowledge. Players have private information about their own types, and they can compute subjective (Bayesian) probabilities for the types of their opponents.

Major arguments that decision and game theories may not be efficient in modeling the behavior of negotiating parties relate to the following two assumptions (Binmore, 1990, Simon, 1996, Castlefranchi and Conte, 1997; Tversky and Kahaneman, 1981):

1. *Assumption regarding the rationality of individuals, who behave as optimizers.* The question of what is optimal, in game theory models, is independent of actual human behavior. The argument here is that the question of how *do* people actually behave has been reformulated to one of how *should* people behave given that each individual were to maximize his utility. Castlefranchi and Conte (1997) state that economic rationality (striving to maximize utility) is not a model of rationality in *general* but only one of a large set of possible human goals. Cognitive scientists claim that game theory does not consider the entire set of a party's goals when formulating the criteria for rational behavior (Simon, 1996). This observation is supported by the fact the rationality assumption is experimentally unsupported (Roth, 1995).

2. *Assumption regarding a complete knowledge about the space of possible actions and their outcomes.* In decision and game theoretic models, the space of alternatives is assumed to be fully known by the parties. Simon (1996) emphasizes that to know a solution *exists* is not to know what the solution *is*. An extension to this criticism, important for our work, is that the negotiating parties often do not believe that a mutually satisfying solution exists, or are unable to recognize one, because of mistrust and bad communication.

However, game theory has proved useful in modeling social interactions in disciplines such as economics, political theory, evolutionary theory, moral and social psychology and sociology. Faratin, (2000, p. 88) utilizes game theory models, because "they hey have the ability to predict and explain social interactions in a manner which does not rely on *post-hoc* explanations (explanations based on coincidental correlations), but rather on some formal notions". Another advantage of game theory (Faratin, 2000, p. 88) is "the ability to conceptualize these interactions in a meaningful and formal prototypical contexts (games) which are appropriate to experimental analysis".

Contribution of cooperative game theory to this work is that it emphasizes *individual preferences* while demonstrating that cooperation and joint gains can emerge from them. Our approach is to adopt some of the formal decision and game theoretic terms and tools, such as outcomes, utilities, reservation values, side payments, and protocols, as well as solution concepts, such as Pareto-optimality, Nash bargaining solution, and the reference point. However, at the same time, we deal with the inadequacy of some underlining assumptions of decision and game theories in depicting the real world by:

1) Providing a dynamic mechanism for creating and modifying during the negotiation rounds the preference structure of objectives and their relative importance,

2) Providing a mechanism for analyzing the joint utility space while assuring an appropriate level of confidentiality;

3) Incorporating a water allocation optimization model into the NSS, to assist the parties in generation and evaluation of alternative negotiation solutions.

3.3 WAS - Generation and evaluation of negotiation alternatives

Decision and game theory models are concerned with selecting the optimal alternative (or strategy) from a set of *a priori* (externally) defined alternatives (strategies). Commonly, they are not aimed at providing assistance at the stage at which the alternatives are being created (Kersten, 1988). In a negotiation process, however, the ability of the parties to create and recognize "good" alternative solutions, directly affects the quality of the negotiation outcome – expressed by the level of the parties' satisfaction. The NSS requires a component that will assist the parties in exploring the field of feasible solutions to the water allocation problem. We adopt a tool that, besides assisting the parties in creating and evaluating alternatives, enables exploring the possibility of achieving additional economic gains.

The Water Allocation System (WAS, Fisher et. al, 2002) is an optimization model which allocates a given quantity of water among the parties, while maximizing the overall net economic benefit from water use. Concepts and features of the model are explained in the following sections.

3.3.1 Economic value of water (following Fisher et al., 2002 and Fisher et al., 2005)

Most solutions to water allocation problems relate to water only in terms of its quantities. Demands for water are projected according to needs of different consumers. Supplies of available water are estimated and whenever the balance between the two shows a shortage, engineering and/or political solutions are sought, to provide more water or somehow allocate the scarce resource. According to this approach, water allocation between two parties that claim rights to the same quantity of water is perceived as a zero-sum game: water allocated to one party is not available to the other. This holds for both within-a-country and international water allocation problems, since the two parties can represent different types of demands in a single country, or, two states (or political entities) that share a water resource.

In recent years, there have been attempts to relate to water in terms of *values*. These attempts are based on the fact that water is valuable not only because it is essential for sustaining human life, but because it is scarce (Eckstein et al., 1994). In the countries that have access to the sea, desalination puts an upper bound on the value of water in dispute (Fisher et al., 2002). Feitelson and Haddad (2001) give as an example the dispute over the Mountain Aquifer between the Israelis and the Palestinians. With desalination as an alternative water resource, the value of the water in this dispute is at most in the range of a few hundred million dollars per year – an amount of money, which should certainly be negotiable.

The economic value of water is expressed through the willingness of a user to pay for a certain amount of water. For the first few units of water a user is willing to pay the highest price. If, for example, this user were a single household, the most valuable units of water would be used for drinking and cooking. Values of the next units of water decrease, since this is the water used to satisfy less essential needs. The willingness to pay is a function of the amount of water used, and is presented by the *demand curve* (Figure 3.3.1).

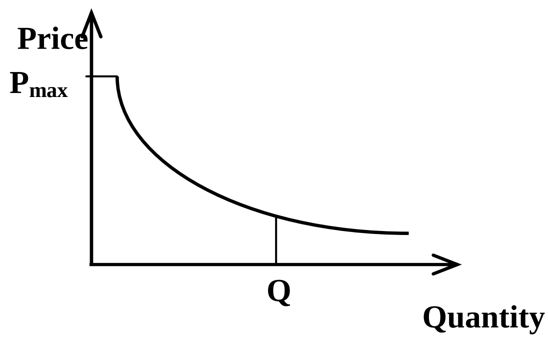

Figure 3.3.1: Demand Curve

When an amount of water, Q, is delivered to a user, the total value of that amount of water to that user is equal to the total area below the demand curve, to the left of Q. To conform to standard mathematical formulations of the function, the curve does not intersect the vertical axis, and instead P_{max} is a cutoff price, which makes the area under the curve finite.

Summation of demand curves of all users of a sector (urban, industrial or agricultural) in a district gives the aggregate demand curve for that sector in that district. If the curve in Figure 3.3.1 represents a sector demand curve and the quantity Q is the total amount of water allocated to this sector, then, the *gross benefits* to that sector are equal to the area below the curve, to the left of Q. These are gross benefits because there are costs of providing the amount Q of water to the district. The *cost function* (Figure 3.2) is an increasing function of the amount of water, and may rise smoothly or in steps corresponding to different supply sources. For any allocation Q, the *net benefits* from the water allocation are calculated by subtracting the total costs of providing the water (the area under the cost curve, to the left of Q) from the gross benefits.

If water allocation is aimed to maximize the net benefits, the amount Q* (the intersection of the two curves, in Figure 3.3.2) is exactly the one to be delivered. A lesser amount of water would mean that the consumer would be willing to pay more for additional units than the cost of such additional units.

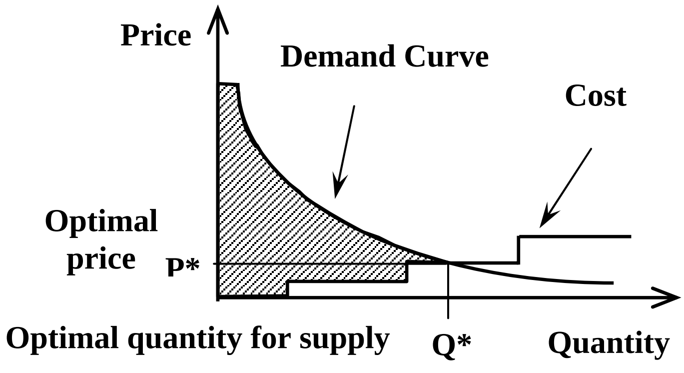

Figure 3.3.2: Demand and Supply Curves

A greater amount of water delivered than Q* would mean that the consumer would not be willing to pay the costs of providing the additional units, and the loss would be the area between the two curves.

These demand curves capture the *private value* of water, the value to the consumer. However, water also has a *social value*, which can exceed the private one. For example, one of the ways for a government to support the agricultural sector is to subsidize its water. In the case of a subsidy by a fixed amount at all quantities, the demand curve would be changed as shown in Figure 3.3.3:

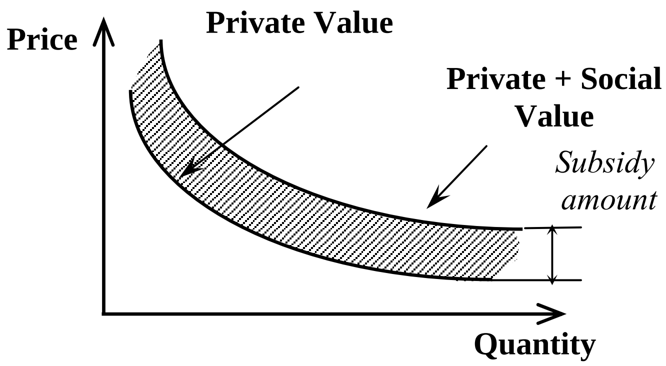

Figure 3.3.3: The effect of a fixed subsidy on the demand curve

This means that this water is worth to society more than farmers are willing to pay for it. The optimal allocation is now determined as the intersection of the cost curve and the new demand curve. This policy would make farmers use more water than without the subsidy.

3.3.2 Shadow Prices and Scarcity Rents

Prices in competitive markets measure the willingness of buyers to pay for additional units of the goods in question (marginal value). When a price is higher than the cost of providing an additional unit (marginal cost), that unit is worth providing. A price less than the marginal cost means that production of that good should be cut back. This system of prices and the profits and losses is a guide for an optimal allocation of goods.

There are many reasons why the laws of perfectly competitive markets cannot be applied in the case of water. A competitive market assumes many private, competitive producers and buyers. Water is usually not supplied privately and competitively by many sellers. Thus, the private value of water can differ from its social value. Another reason is that, because of the scarcity of water, pumping in one location may affect the availability of water in another location of the same source (e.g., aquifer).

If, in Figure 3.3.2, Q* were the maximum amount of water available, then, P* would represent the price which consumers would be willing to pay to obtain an additional unit of water. This price is called the *shadow price* of water. It can be also defined as the amount of increase in net-benefits to water users that would be obtained from the availability of that additional unit of water.

The shadow price of water in a given location is not necessarily equal to the direct (marginal) cost of producing it there. If demand from a limited water source with zero pumping cost is sufficiently high, the shadow price of that water would not be zero. Consumers at that location would be willing to pay a positive price for water, even though its direct production and supply costs are zero. This positive value of water *in situ* is called a *scarcity rent*. When the direct costs of providing the water are zero, the scarcity rent equals the shadow price of water (Figure 3.3.4).

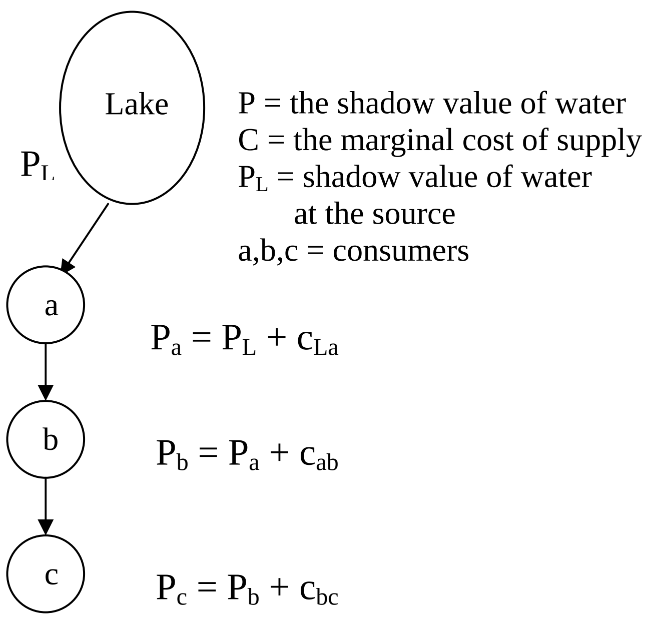

Figure 3.3.4: Scarcity rent and shadow prices

Accordingly, in a given location, the shadow price is the sum of the scarcity rent of water and the direct marginal costs of providing it at that location.

3.3.3 Water Allocation System (WAS)

The methodology for optimal allocation of water has been embedded in the Water Allocation System (WAS) model. The area in question, covering the territory of one or more countries (or political entities), is divided into ‘districts’. Each district has sources, consumer sectors (urban, agriculture, industry, nature), and is connected to other districts or to a central conveyance system. Physical and economic data are given for the districts, consumer sectors, and the connecting conveyance system. The model maximizes the total net benefit by allocating water among all districts and sectors, subject to physical, political, administrative and any other imposed constraints. The model can also include recycling wastewater and seawater desalination.

Depending on the users’ definition, water resources in the WAS model can be treated as *common pools* with respect to a group of consumers, so that no constraints are imposed a-priori on the allocation of the water from these sources among them. But there is the possibility to constrain these allocations by defining a minimum, maximum, or a fixed quantity of water to be allocated to particular consumers, districts or countries (political entities).

The basic assumptions that underlie the economic approach of the model are:

- Water has value not only because it is important for sustaining human life or for other uses, but because of its scarcity. Where water is scarce, there is a private willingness to pay relatively large sums for small amounts of water. Where water is not scarce, i.e. there is an unlimited supply, it has no economic value.
- Water can have a social value higher than its private value. The excess of the social over the private value of water can be reflected in a subsidy.
- Water ownership is a property right entitling the owner to the economic value of the water. This is true regardless of who actually uses the water.

- An owner will use a given amount if its water if and only if it values that use at least as much as the money he would gain from selling the water to another user. The non-owner will decide to buy if and only if he values the water at least as much as the money involved in the purchase.
- Economically efficient (optimal) water use does not depend on water ownership (for example, resolving the question of where water can be pumped efficiently does not depend on who owns it).
- Water cannot be worth more that the cost of replacing it. In the model, the possibility of desalinating seawater puts an upper bound on the value of water in localities where this technology can be used.
- Voluntary trade is always a win-win situation for both the buyer and the seller. When one party values a quantity of water less than the proposed selling price, and the other values that same quantity more than its price, them both parties gain if the former sells to the latter. No party in the system sells any water unless he finds it beneficial to do so.

The model is based on average annual conditions. Each country is divided into districts where water is supplied and/or used. Data for supply, demand, and water treatment for each district as well as data on conveyance between districts (by pipeline or natural channels) are incorporated in the model. The model considers water demand by three sectors: households, industry, and agriculture. It takes private demand curves of all sectors in all districts and accounts for the social value of water defined by national policies. National policies can be of the following types:

- A limit on extraction from each source, resulting from hydrological, environmental, political or other considerations.
- A minimum amount of water to be supplied to a consumer.
- A fixed amount of water to be supplied to a consumer.
- The maximum amount of water which will be provided to a consumer, even if he is willing to buy more.
- A subsidy given to the water supplied to a consumer.
- A price assigned to each quantity of water, which can be different from the real cost of producing it (this could reflect, for example, the value of water in situ, such as for preservation of natural assets).

Water production in each district is defined by its price function. This function is expressed as a step function: for a given range of water quantities there is a specified cost per cubic meter.

The demand of water by each sector in each district is given by a demand function, which gives the quantity of water that consumers will purchase and use, as a function of the price they are charge for the water.

Given the conditions and constraints specified by the user, the model allocates the available water so as to maximize net economic benefits from water use. Shadow values of water are generated as part of the solution. The model can be used to compute the economic benefits of proposed infrastructure projects. Where two districts not connected by pipeline, river, or channel, have shadow prices that differ by more than the estimated cost per unit of water of a conveyance system between them, construction of such a pipeline is economically justified.

By running the model with and without a projected infrastructure project, the planner can find the increase in annual benefits that a project would generate, compare them to the cost of the project and decide whether the project is justified economically.

Water allocation scenarios. WAS can be run in a *countrified* version, where the area in question is a single country, with water quantities available from sources shared with its neighbors defined a-priori. Another option is to run WAS for the region of two or more countries (the *regional* version), in which case shared water resources are treated as common pools (on the international level). Both types of WAS runs can be performed to reflect various sets of physical, political, administrative and other constraints. Each set of data and constraints produces a *water allocation scenario* (countrified or regional). The set of WAS output data includes the optimal allocations, total net benefit from water use, shadow prices of water for the consumers and districts, shadow values of constraints, including scarcity rents for water in the sources.

WAS Mathematical formulation. The WAS model is written in the GAMS (Generalized Algebraic Modeling System) language, with the MINOS non-linear optimization module.

For demand curves described by $P = B \times Q^{\alpha}$, where P and Q are the price of a unit of water and the supplied quantity of water, respectively, and B and α are coefficients (α is the coefficient of elasticity of the demand curve), the optimization problem is formulated as follows:

$$\begin{aligned} Max \quad Z = & \sum_i \sum_d \left[\frac{B_{id} \times (QD_{id} + QFRY_{id})^{\alpha_{id}+1}}{\alpha_{id}+1} \right] - \sum_i \sum_s QS_{is} CS_{is} - \\ & - \sum_i \sum_j QTR_{ij} \times CTR_{ij} - \sum_i \sum_d QRY_{id} \times CR_{id} - \\ & - \sum_i \sum_j QTRY_{ij} \times CTRY_{ij} - \sum_i \sum_d \left[CE_{id} \times (QD_{id} + QFRY_{id}) \right] \end{aligned} \qquad (3.3.1)$$

Subject to:

1. *Preserved mass-balance of fresh water for sector d in district i:*

$$\sum_d QD_{id} = \sum_s QS_{is} + \sum_j QTR_{ji} - \sum_j QTR_{ij} \quad \forall i \qquad (3.3.2)$$

2. *Preserved mass-balance of recycled water for sector d in district i:*

$$\sum_d QFRY_{id} = \sum_d QR_{id} + \sum_j QTRY_{ji} - \sum_j QTRY_{ij} \quad \forall i \qquad (3.3.3)$$

3. *Quantity of water recycled from use d in district i:*

$$QRY_{id} = PR_{id} \times [QD_{id} + QFRY_{id}] \quad \forall i,d \qquad (3.3.4)$$

4. *Lower limit on the total quantity of water (fresh and recycled) demanded by sector d in district i:*

$$QD_{id} + QFRY_{id} \geq \left[\frac{PMAX_{id}}{B_{id}} \right]^{1/\alpha_{id}} \quad \forall i,d \qquad (3.3.5)$$

5. *Upper limit on the quantity of water supplied to district i from source s:*

$$QS_{is} \leq QSMAX_{is} \quad \forall i,s \qquad (3.3.6)$$

6. *Upper limit on the percent of water recycled from sector d in district i:*

$$PR_{id} \leq PRMAX_{id} \quad \forall i,d \qquad (3.3.7)$$

All variables positive

Where: Indices are:

i = district (i alias j);

d = demand type (urban, industrial, agriculture);

s = supply source;

Parameters are:

α_{id} = exponent of inverse demand function for demand d in district i;

B_{id} = coefficient of inverse demand curve for demand d in district i;

CE_{id} = unit environmental cost of water discharged by demand sector d in district i;

CR_{id} = unit recycling cost of water supplied from demand sector d in district i;

CS_{is} = Unit cost of water supplied form supply step s in district i;

CTR_{ij} = unit cost of water supplied from district i to district j;

$CTRY_{ij}$ = unit cost of recycled water transported from district i to district j;

$PRMAX_{id}$ = maximum price of water for demand sector d in district i;

$QSMAX_{is}$ = maximum amount of water from supply step (source) s in district i;

P_{id} = shadow price of water for demand sector d in district i (computed).

Variables are:

Z = net economic benefit from water use;

QS_{is} = quantity of water supplied by source s in district i;

QD_{id} = quantity of water demanded by sector d in district i;

QTR_{ij} = quantity of freshwater transported from district i to district j;

$QTRY_{ij}$ = quantity of recycled water transported from district i to district j;

QRY_{id} = quantity of water recycled from use d in district i;

$QFRY_{id}$ = quantity of recycled water supplied to use d in district i;

PR_{id} = percent of water recycled from sector d in district i;

The WAS model can be used by each party in a pre-negotiation (preparation) stage. A party can impose various assumptions about its share in disputed sources and options for inter-connecting neighboring systems, and evaluate his own position with respect to regional cooperation.

Chapter 4

The Negotiation Support Model

4.1 Introduction

In this work, negotiation is viewed as an iterative (multi-round) and interactive (the parties exchange information, views, positions) process. In each round, the parties perform their own evaluation of the interim results reached so far, the last proposals that have been made, and their contribution to meeting its objectives. The results guide the party in the next round, to maintain or change its position, preferences, and proposals, bringing these into the arena of joint evaluation. The process ends when the parties decide that they have reached an acceptable negotiated solution, or when a party decides to break off the negotiations (and accept its BATNA). This process is supported by the Negotiation Support System (NSS) which is depicted in Figure 4.1.

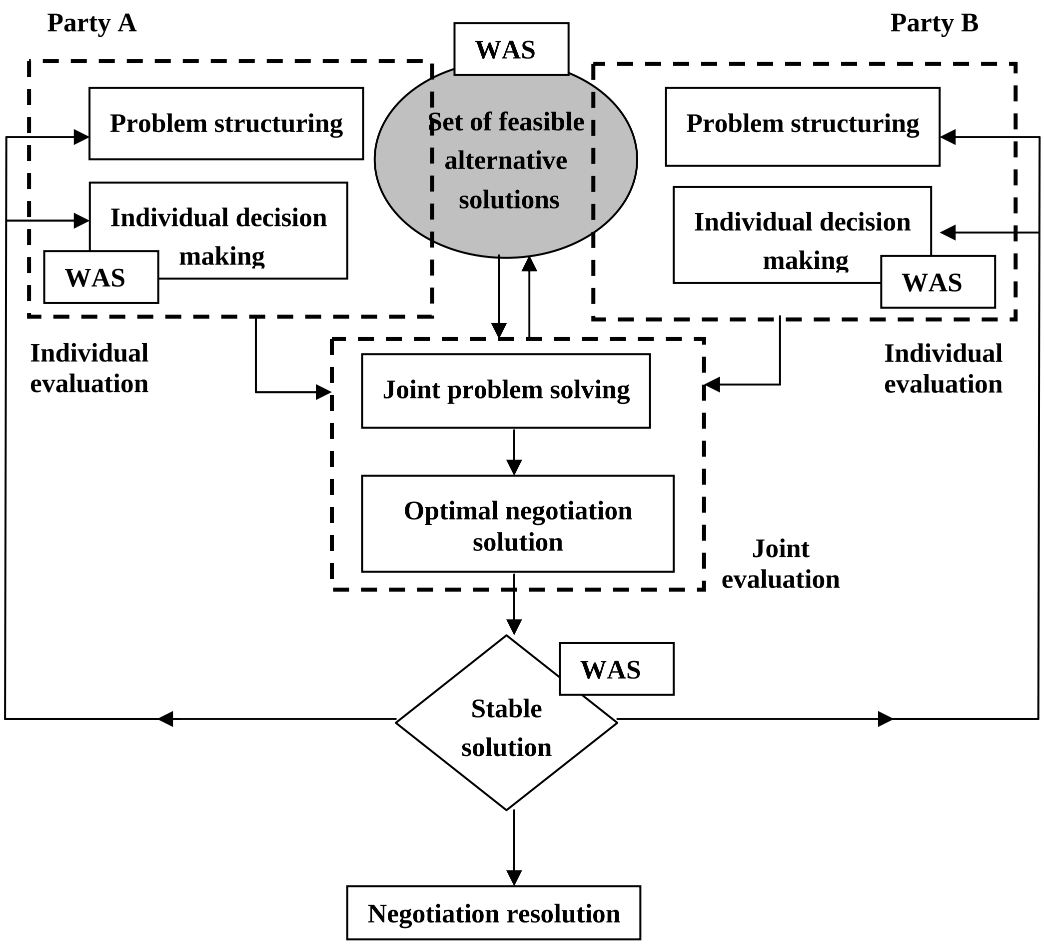

Figure 4.1: The Negotiation Support System

The negotiation is modeled as a combination of two processes: individual decision-making and joint problem solving. The parties have to operate in two contexts: jointly, as negotiators, and individually, as decision-makers in their own domain of interests. The negotiation support model includes tools for assistance in both individual and joint decision-making. The individual decision support is designed to assist the parties in structuring and analyzing their own systems of preferences. An underlying assumption of the approach is that a thorough and well organized individual analysis of the problem and the related preferences is a precondition for reaching mutually satisfying integrative negotiated solutions. *Joint problem solving* is modeled as an interaction through which the parties have the opportunity to design and select jointly preferred solutions.

A central tool of the overall NSS is the Water Allocation System (WAS), which provides assistance in both the individual and joint decision making processes. It can be used in all the steps of the negotiation process, from the design and proposal of alternative negotiation solutions to the analysis and evaluation of the impacts of these solutions on the objectives of each of the negotiating parties.

The design of the NSS is based on the assumption that the parties' subjective view of the water allocation problem, of the competition for the resource and of the potential conflict which is at its basis, as well as the "state of the world", may change as a result of the change in their perceptions and positions during the negotiations. The "position" of a party depends on how far the party is from achieving its objectives. Changes in the parties' perception of the negotiation problem directly affect two basic elements of the negotiation process:

a. The set of solutions to the negotiation problem which are considered admissible;

b. The objectives and the preference structure of the negotiating parties.

The NSS is designed to allow and account for the changes in these two features of the negotiations. The basis for the negotiation support is the set of alternative negotiation solutions available (known, proposed) at each round of the negotiations. The negotiation process is perceived as an alternating sequence of activities by which the parties manipulate the set of alternative negotiation solutions. These activities are aimed at enlarging the set of alternative solutions (by creating and proposing new ones) and narrowing the set of alternative solutions by removing non-efficient ones, and eventually, moving towards better joint outcomes. The connectors between the elements of the flowchart of the NSS (Figure 4.1) indicate that the manipulation of the set of the alternatives is a result of both individual and joint decision-making. The set of alternatives is enlarged when a new solution is offered. A new offer can be designed by a single party, by a mediator, or jointly by the two parties. Removal of non-efficient offers is determined by the individual preference structures of both parties, and is supposed to leave at its termination a single solution as the final negotiation resolution.

Enlarging and narrowing the set of the alternatives are repeated in an iterative manner, regulated by the protocol of interaction. The iterative process allows the parties to revise their preference structure during the negotiations and evaluate the dynamic set of the alternative solutions. Each iteration consists of the following steps:

a. generation (design) of alternatives;
b. evaluation of alternatives;
c. individual structuring of the preferences;
d. selection of the best accepted alternative;
e. test for the stability of this solution.

The next two parts of this Chapter give detailed explanations of the basic principles of the NSS (Part 4.2), and a presentation of the decision-support tools included in the model (Part 4.3).

4.2 Basic principles of the model

4.2.1 Negotiation protocol (protocol of interaction)

Negotiation is a joint problem solving process during which the parties have to communicate and interact, using an *interaction protocol*. The quality of communication will determine quite significantly the value and stability of the outcome. Parties who claim rights to the same water resource typically presume to have mutually conflicting interests and are therefore inclined to bargain in a distributive manner. They often find themselves locked in situations in which it seems impossible to reconcile the differences, and could therefore prefer to break off the negotiations. The protocol of interaction should reduce the probability that this will occur. It is motivated by normative models of interaction, such as the models of game theory (*normative* refers to prescriptive rules of the game, Chapter 3).

The protocol of interaction consists of rules which specify the modes of interaction. It is commonly modeled by an alternating sequence of offers and counter-offers. In our work the negotiation protocol does not require an alternation of offers. In contrast, it prescribes an alternation of two procedures, alternative-generation and alternative-evaluation, designed to move towards negotiated solutions that improve the achievements of *both* parties. A new alternative solution may be offered by one or both of the parties, or by a mediator, ignoring who offered previous ones. Generation of alternatives is supported by the WAS model, which enables analysis of various inter- and intra-country water allocation scenarios. Alternative-evaluation is procedure in which the negotiators act as individual decision-makers. The individual decision-making process is based on pair wise comparison of the proposed alternative solutions and of the elements of the negotiators' preference structures. The two processes, alternative-generation and alternative-evaluation, are repeated in a sequence of iterations, which terminates when a stable solution is reached.

4.2.2 Alternative negotiation solutions (alternatives)

On a *public* level (in terms of shared information), the parties negotiate the allocation of two commodities: water and an economic value. From the perspective of party $\boldsymbol{i}$,

$\boldsymbol{i = \{A,B\}}$, a negotiation alternative $\boldsymbol{a}$ is represented by the allocated quantity of water from the disputed resource, $\boldsymbol{Q_i(a)}$, measured in units of volume, and a monetary value $\boldsymbol{v_i(a)}$. The sum of the allocated quantities of water, $\boldsymbol{Q_A(a)} + \boldsymbol{Q_B(a)}$, is constant over all the alternatives and equals the amount of water to be shared between the parties from the disputed source. (Since water sources are always subject to random variability, this is usually set to be the agreed upon average annual renewable potential of the water source; considerations of source uncertainty, an important aspect of water allocation, is beyond the scope of this study). We obviously deal with cases in which the total amount of water required by the parties is more than the available quantity, and therefore an alternative that allocates less than all the available water is not efficient, and is not relevant in our analysis.

$\boldsymbol{v_i(a)}$ is the net economic gain to party $\boldsymbol{i}$ from alternative $\boldsymbol{a}$. If, for example, alternative $\boldsymbol{a}$ reallocates the disputed water resource so that party $\boldsymbol{A}$ gains an additional quantity of water, the economic value of the total quantity of water available to $\boldsymbol{A}$ increases, according to its water demand curve. Correspondingly, party $\boldsymbol{B}$ loses the same quantity of water, so that the economic value of its allocated water decreases. In order to make such an alternative attractive to party $\boldsymbol{B}$, $\boldsymbol{A}$ can offer $\boldsymbol{B}$ a *side payment* (see Section 3.2.2.1). $\boldsymbol{v_A(a)}$ and $\boldsymbol{v_B(a)}$ are the net economic gain or loss that accrue to each party by selecting alternative $\boldsymbol{a}$ over a reference alternative $\boldsymbol{a_r}$. The sum $\boldsymbol{v_A(a) + v_B(a)}$, varies over the alternatives, and is calculated relative to the reference alternative $\boldsymbol{a_r}$. If alternative $\boldsymbol{a}$ is (economically) efficient, this sum will be positive.

On a *private* level (in terms of confidential information), each party evaluates the efficiency of alternative solutions to the problem according to a set of its own criteria. The set of criteria of one party is independent of the set of criteria of the other party. In terms of decision-making theory, these criteria are the parties' objectives or attributes. Party $\boldsymbol{i}$ can assess the “quality” of alternative $\boldsymbol{a}$ by analyzing the "performance" of the corresponding bundle, $\boldsymbol{(Q_i(a), v_i(a))}$, with respect to each of his objectives. If $\boldsymbol{u_i^j(a)}$ is a subjective measure (score) of the degree to which alternative $\boldsymbol{a}$

satisfies objective j, $j = 1,\ldots,n$, then, for party i, alternative a represents the n-tupple $[u_i^1(a),\ldots,u_i^n(a)]$, with n being the number of party i's objectives (criteria). The subjective measures, $u_i^j(a)$, result from an evaluation of alternative a, as part of i's individual decision making process, and will be explained further in Section 4.3.

4.2.2.1 Design of alternatives

The parties design alternative solutions while using, individually or jointly, the WAS model. Each party can analyze the effects of a solution that has been tabled or of a solution he is considering to offer, according to the output of a corresponding run of WAS. For this purpose, there are a few basic results of WAS that are relevant on the public level and which figure in the bargaining process. Let Q_{DS}, $Q_i(a)$, $q_i(a)$, and $V_i(a)$ denote the following:

Q_{DS} = the average annual renewable quantity of water in the disputed source;

$Q_i(a)$ = quantity of water from the disputed resource, allocated to party i, $i=\{A,B\}$, according to alternative a;

$q_i(a)$ = WAS-optimal quantity of water from the disputed resource, to be supplied to the consumers in i, given $Q_i(a)$ ($q_i(a) \leq Q_i(a)$). $q_i(a)$ can vary as a function of intra-country water allocation arrangements (see Chapter 3);

$V_i(a)$ = the annual net economic benefit of party i from the use of water allocated to it in alternative a. It is the net benefit from the total annual consumption of water in i, when the annual available supply of water includes $q_i(a)$: $V_i(a) = V_i(Q_i' + q_i(a))$, where Q_i' is the annual renewable quantity of water available to i which is not subject of negotiation. Like $q_i(a)$, $V_i(a)$ varies as a function of the domestic water arrangements (scenarios). In case party i considers S scenarios which include $Q_i(a)$, the annual net economic benefit to i will be denoted by $V_i(a^s)$, $s = 1,..,S$.

In any negotiated alternative a, Q_{DS} can be allocated in one of the two following ways:

a. it can be allocated *a priori* to the parties in quantities $Q_A(a)$ and $Q_B(a)$, (so that $Q_A(a) + Q_B(a) = Q_{DS}$), where each party analyzes the intra-country water-allocation scenarios *posteriori*, given $Q_i(a)$, $i = \{A,B\}$;

b. $\boldsymbol{Q_{DS}}$ can be defined as a *common pool* (Chapter 3); in this case, the regional version of the WAS model determines the optimal allocation so as to maximize the *joint* net benefit from water consumption in the combined area of both countries. The allocated quantities of the disputed resource ($\boldsymbol{Q_A(a)}$ and $\boldsymbol{Q_B(a)}$) and the net benefit from water use in the two countries will be different for different regional scenarios.

Both types of alternatives can have elements of a regional cooperation.

4.2.3 Economic efficiency of negotiated alternatives (creating 'new' value)

Let $\boldsymbol{a_r}$ and $\boldsymbol{a}$ be two alternatives and $\boldsymbol{V_i(a_r), V_i(a), i = \{A,B\}}$ the net economic benefits of party $\boldsymbol{i}$ from the water consumption in cases $\boldsymbol{a_r}$ and $\boldsymbol{a}$, respectively. $\boldsymbol{\Delta v_i(a_r,a)}$ is the change in the net benefit to party $\boldsymbol{i}$ obtained by moving from $\boldsymbol{a_r}$ to $\boldsymbol{a}$: $\boldsymbol{\Delta v_i(a_r,a) = V_i(a) - V_i(a_r)}$, and it can be positive, negative, or zero. The two parties jointly create 'new' economic value if when they move from $\boldsymbol{a_r}$ to $\boldsymbol{a}$ the sum of the changes in the net benefits, $\boldsymbol{\Delta v_A(a_r,a) + \Delta v_B(a_r,a)}$ is positive. That is, alternative $\boldsymbol{a}$ is economically more efficient than a_r if:

$$\boldsymbol{V_A(a) + V_B(a) > V_A(a_r) + V_B(a_r)}.$$

A negotiator who makes decisions based on a pure economic rationality would agree to select alternative $\boldsymbol{a}$ over alternative $\boldsymbol{a_r}$, only if $\boldsymbol{a}$ would improve the resulting net economic benefit to his own country, that is, if $\boldsymbol{\Delta v_i(a_r,a)}$ is positive. Accordingly, he would be indifferent between the two alternatives if $\boldsymbol{\Delta v_i = 0}$, and would reject $\boldsymbol{a}$ if $\boldsymbol{\Delta v_i < 0}$.

Whenever $\boldsymbol{a_r}$ and $\boldsymbol{a}$ allocate $\boldsymbol{Q_{DS}}$ so that $\boldsymbol{Q_A(a_r) + Q_B(a_r) = Q_{DS}}$ and $\boldsymbol{Q_A(a) + Q_B(a) = Q_{DS}}$, with $\boldsymbol{Q_i(a_r) \neq Q_i(a), i = \{A,B\}}$, and the sum of the changes in the net benefits, $\boldsymbol{\Delta v_A(a_r,a) + \Delta v_B(a_r,a)}$ is positive, the annual net benefit from water use of one party increases while of the other decreases. The way 'new' economic value is created in the case of the '*a priori* allocation' and 'common pool' alternatives, is explained in the following:

a. *A priori* allocation

Let ***a*** be an alternative to be compared to the reference alternative a_r, and let ***A*** denote the negotiating party with a higher marginal value of water, given alternative a_r. The sum $\Delta v(a_r,a) = \Delta v_A(a_r,a) + \Delta v_B(a_r,a)$ will be positive if alternative ***a*** allocates to party ***A*** a quantity of water $Q_A(a)$ so that $Q_A(a) > Q_A(a_r)$, as shown in Figure 4.2a.

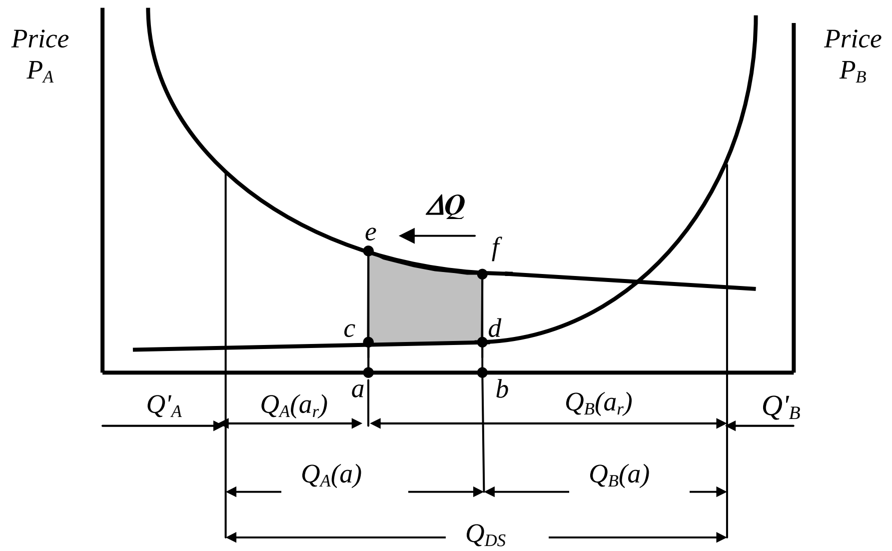

Figure 4.2a: 'New' economic value – *a priori* allocation. Q'_A, Q'_B = quantities of water that are not subject to the dispute; Q_{DS} = total quantity of water in the disputed source; $Q_A(a_r)$, $Q_B(a_r)$ = allocations of water to A and B according to reference alternative a_r; $Q_A(a)$, $Q_B(a)$ = allocations of water according to alternative *a*; ΔQ = quantity of water transferred from B to A.

$\Delta v(a_r,a)$ is positive because the quantity of water $\Delta Q = Q_A(a) - Q_A(a_r)$, transferred from ***B*** to ***A*****,** is valued more when consumed by party ***A***. Relative to a_r, alternative ***a*** increases the economic value of water of party ***A*** by the value of area *abfe*, and decreases the economic value of party ***B*** by the value of area *abdc*. The net increase in joint economic value is positive and shown by the dark area *cdfe*.

If, according to alternative ***a***, a ΔQ is transferred from the party with a higher marginal value of water to the party with a lower marginal value (marginal values according to alternative a_r), the resulting total change in the economic value of the water consumed in both countries will be negative. ***a*** is, then, an economically inefficient solution, relatively to alternative a_r.

b. Common pool

In case the parties agree to consider a "common pool" alternative, the regional version of the WAS model will determine the optimal allocations, $\boldsymbol{Q_A(a)}$ and $\boldsymbol{Q_B(a)}$, subject to the set of the constraints defined jointly by both parties. $\boldsymbol{Q_{DS}}$ will be allocated so that the joint net benefit for the two countries will be maximal, given the set of constraints. Still, in a common pool alternative constraints in WAS can be used to control the conditions of domestic water allocation arrangements in both countries (see Chapter 3). Figure 4.2.b shows a simplified example of a common pool alternative. In case of zero water supply costs, and no limitations regarding $\boldsymbol{Q_A(a)}$ and $\boldsymbol{Q_B(a)}$, $\boldsymbol{Q_{DS}}$ will be allocated so that the marginal values of water in the two countries will be equal.

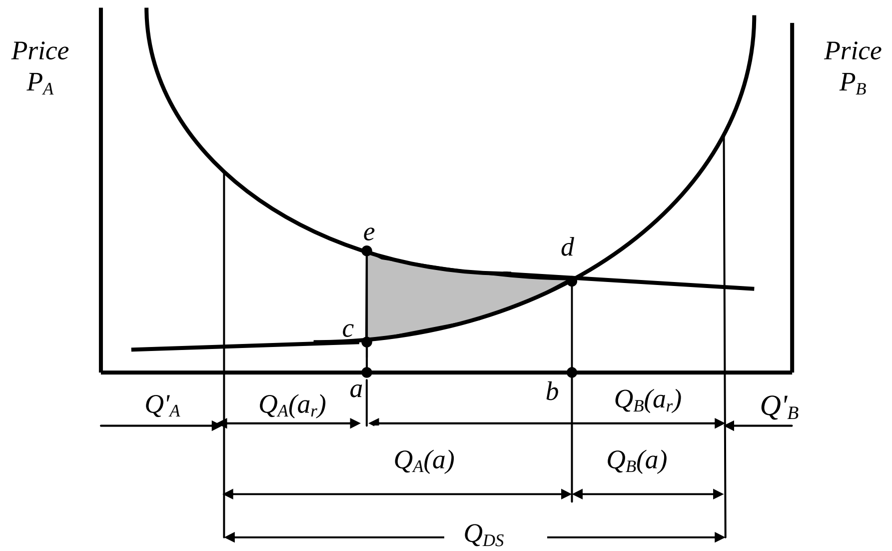

Figure 4.2b: 'New' economic value – a 'common pool' alternative. Q'_A, Q'_B = quantities of water that are not subject to the dispute; Q_{DS} = total quantity of water in the disputed source; $Q_A(a_r)$, $Q_B(a_r)$ = allocations of water to A and B according to reference alternative a_r; $Q_A(a)$, $Q_B(a)$ = allocations of water according to alternative *a*.

The NSS does not assume that the negotiators are driven by economic rationality only. Still, to compensate for a decrease in its water allocation a party may agree to accept a *side payment* as compensation.

A side payment, $\boldsymbol{v_{SP,\, i \rightarrow j}}$, is a monetary value, transferred from party ***i*** who gains an increase in the net benefit from water use, to party ***j*** whose net benefit decreases. The size of this payment is subject to negotiation (bargaining) between the parties, and once agreed upon, it serves for the calculation of the final net economic gain of the parties, earned by moving from $\boldsymbol{a_r}$ to economically more efficient alternative $\boldsymbol{a}$.

The alternatives are generated at the start of each negotiation iteration. Figure 4.3 shows the protocol for generation of an *a priori* allocation alternative. The procedure starts with offer (that can come a party or from the outside) to divide $\boldsymbol{Q_{DS}}$ into quantities $\boldsymbol{Q_A(a)}$ and $\boldsymbol{Q_B(a)}$. Given these allocations, the parties individually explore their domestic water allocation, using the countrified version of the WAS model. A party can analyze a number of domestic scenarios, each subject to a set in-country constraints and demand functions (see Chapter 3).

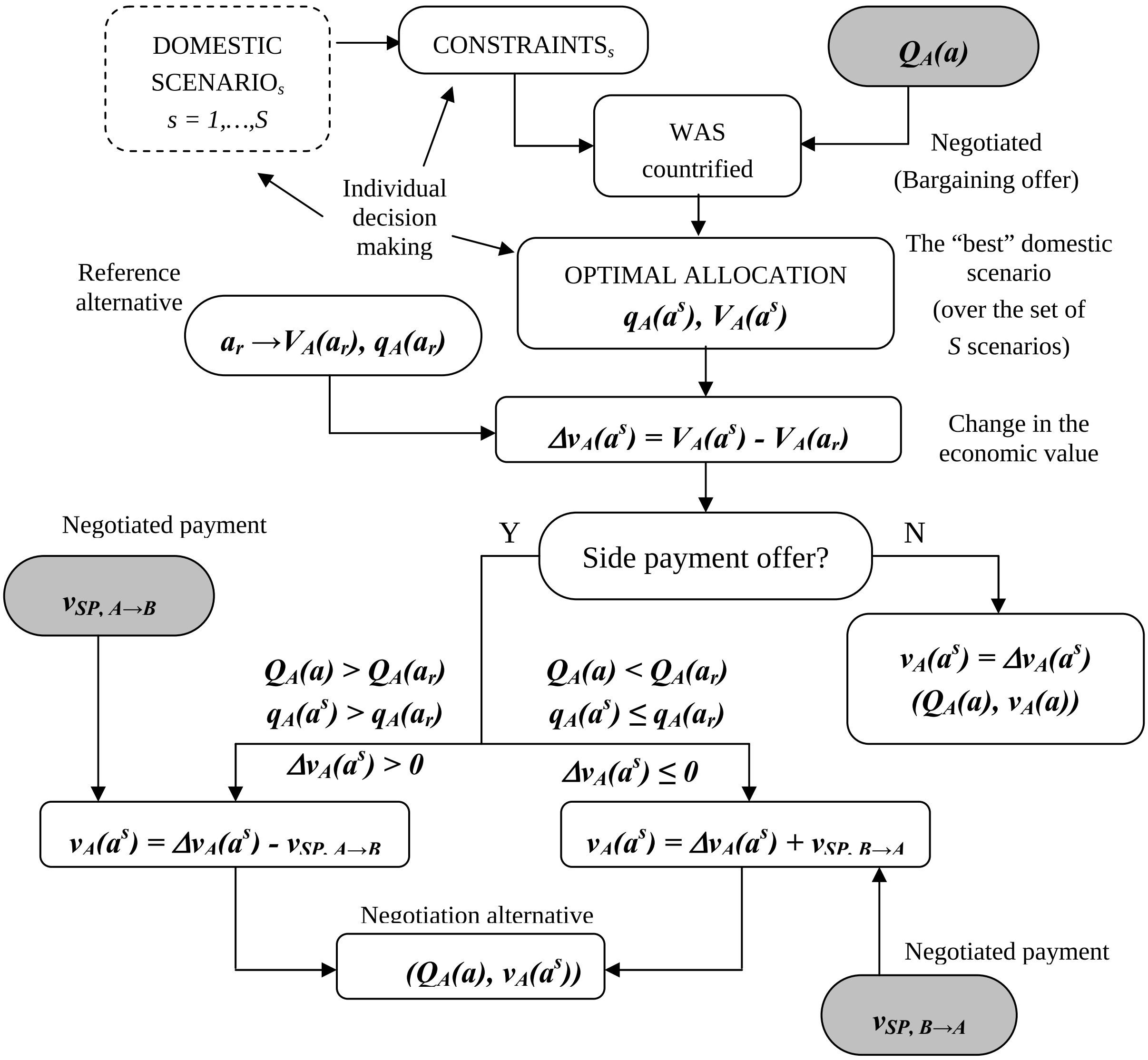

Figure 4.3: Generation of an alternative: *a priori* allocation.

While the parties conduct this analysis they can consider offering a side payment to the party that will be getting a lower water allocation, in order to make the alternative more attractive. The flowchart in Figure 4.3 shows the side payment protocol for economically rational parties: ***A*** will consider offering a side payment to ***B*** only if $Q_A(a) > Q_A(a_r)$, and $q_A(a) > q_A(a_r)$, that is, if alternative ***a*** increases the allocation of Q_{DS} and there exists a domestic scenario ***s*** such that a^s increases the total net benefit from water use to its country. Accordingly, ***A*** would demand a side payment from ***B*** in case $Q_A(a) < Q_A(a_r)$, and $\Delta v_A(a^s) \leq 0,\ \forall s$. However, the NSS does not assume or require economic rationality – a side payment can be offered and accepted for reasons other than economic efficiency. For example, a party which offers a side payment to gain more water may still consider applying a domestic scenario which includes some economically inefficient actions, and eventually decreases the total economic value. The party may, for example, consider desalination of seawater at costs higher than the shadow prices, in order to reduce the supply from fresh-water resources for environmental reasons. This party would not be considered "economically rational", but rather “environmentally aware”.

Figure 4.4 shows the protocol for generation of a “common pool” alternative. Here, a WAS scenario is regional, created through a combination of individual and joint decision processes. Constraints that regulate the domestic water allocation in one country affect the conditions for optimal domestic allocation in the other country, and *vice versa*. For example, if one country decides to subsidize its consumers so they will use more water, it will exacerbate water scarcity conditions in the other country; (This case is discussed by Fisher et al., 2005, who analyzed the effects of a hypothetical subsidy to Israel’s agriculture on water availability and economic benefits from water use in the Palestinian National Authority). Within the framework of the NSS, a “common pool” alternative is considered a cooperative alternative created jointly by the parties. This means that constraints and actions that regulate domestic water allocations in both countries are also jointly accepted, and that, if required, compensating side-payments can be negotiated. Otherwise, the parties would not have any incentive to cooperate.

For a given scenario, the resulting allocations, $Q_A(a)$ and $Q_B(a)$, maximize the joint (regional) net benefit, V_{AB}. In a "common pool" alternative, $q_i(a) = Q_i(a)$ and $\Sigma Q_i(a) = Q_{DS}$, $i = A,B$ (theoretically, the "optimal" allocations can sum up to a quantity which is less than Q_{DS}, but under conditions of regional water scarcity this is never the case). The net economic value to the parties is calculated in the same way as in the case of an *a priori* allocation alternative.

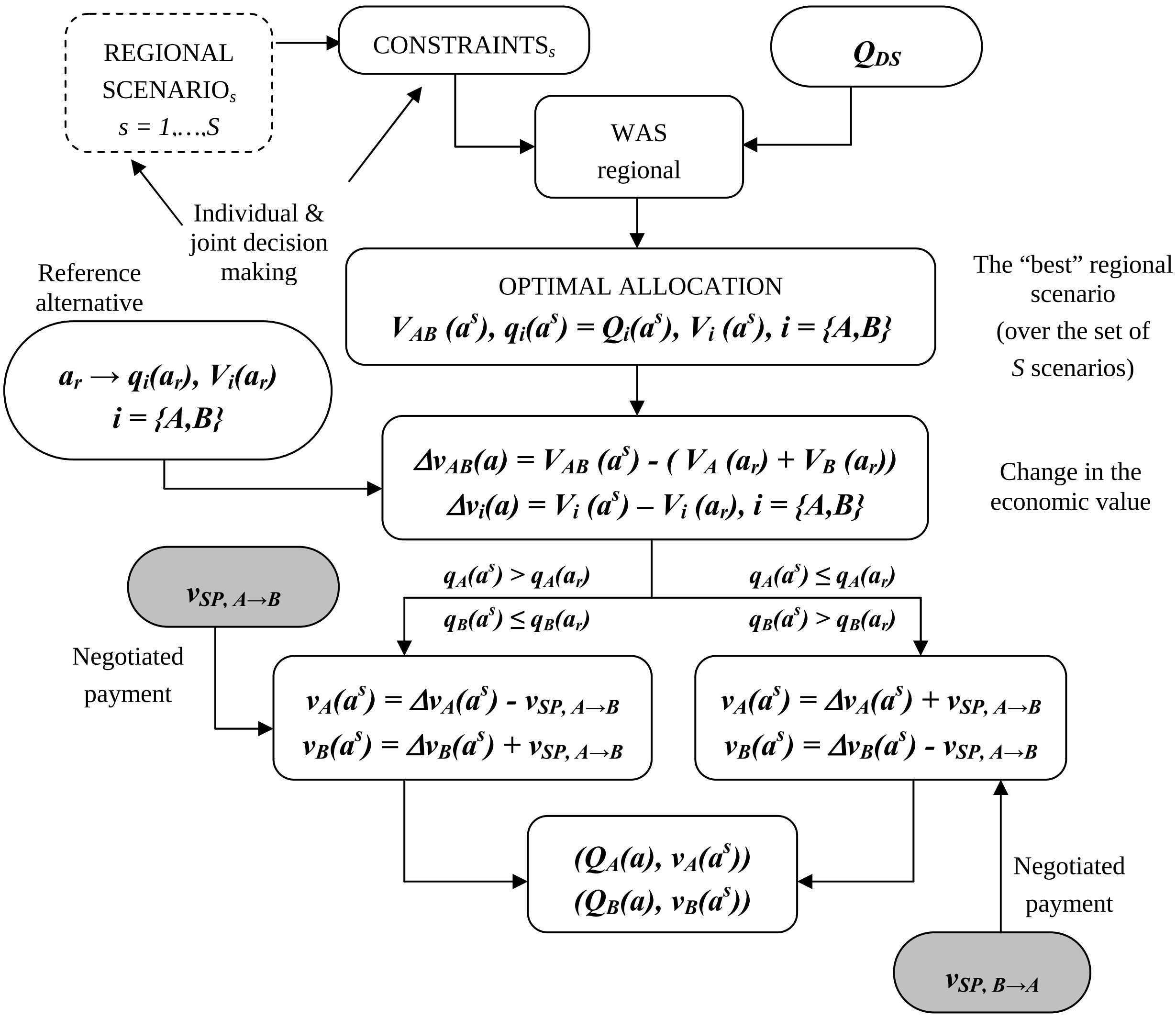

Figure 4.4: Generation of an alternative: common pool.

4.3 Components of the Negotiation Support Model

4.3.1 Individual decision support

Individual evaluation of the alternatives is a sequence of preference-setting procedures (performed by the party as the decision maker) and calculations (performed by the tool for individual decision support), which map the alternatives from the alternative space into an *n*-dimensional individual consequence space, with *n* being the number of the evaluation criteria. A utility function, defined over the individual consequence space, assigns a single value to each alternative, and expresses the party's overall satisfaction with that alternative.

The individual decision support (IDS) model assists the parties at each iteration: to (a) structure the water allocation problem into a set of the criteria relevant for that iteration, and (b) qualitatively and quantitatively evaluate the alternative solutions of that particular iteration. The utility function defined over the individual consequence space is the final result of the quantitative and qualitative analysis. The model for individual decision support utilizes the Analytic Hierarchy Process (AHP, Saaty 1980, Shamir et al., 1985) for individual structuring (presentation and evaluation) of the water allocation problem (see Section 3.1.5). The hierarchy of each party consists of three levels as shown on the example in Figure 4.5.

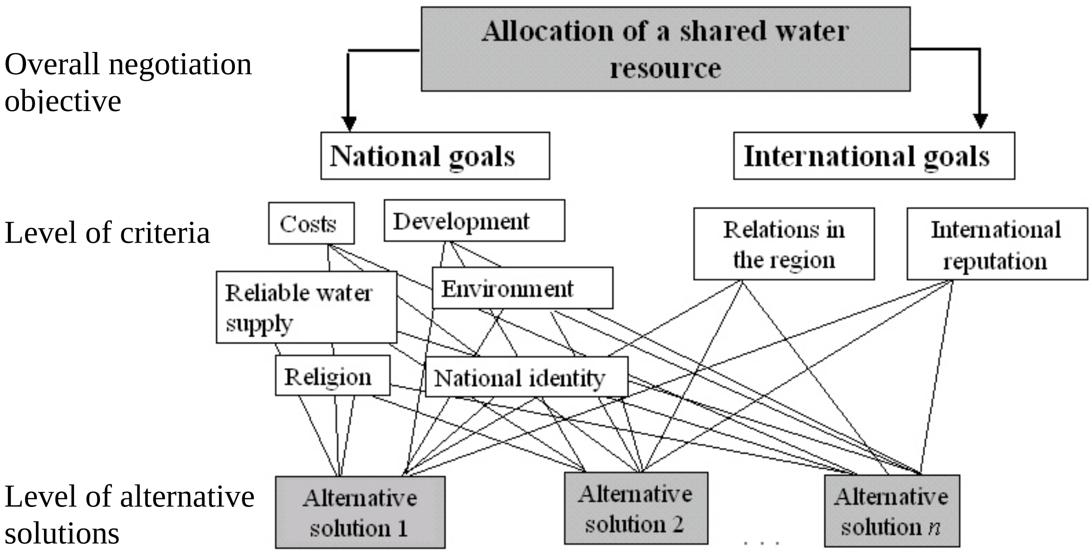

Figure 4.5: Individual hierarchical (3-level) structure of the international water allocation problem (an example)

The first (top) level represents the overall aim of the party, the second the party's objectives (criteria), while the third level consists of the examined alternative solutions. The first and the third level of both parties' hierarchies are identical and publicly known at each stage of the negotiations. The elements of the second level, namely the criteria for the evaluation (and their relative weights), are specific to each party and assumed to be confidential.

4.3.1.1 Model of objectives (criteria)

Generally, the objectives (criteria) can be of two types:

1. Quantitative objectives, which can take values measurable in their characteristic units. For example, *reliable supply* and *economic efficiency (net benefit) from water use* are objectives measured in units *mcm/year* and *$million/year*, respectively.
2. Qualitative objectives that cannot be measured by any standard units, such as *national security* or *social stability*.

The negotiation framework is based on dynamic evaluation of the objectives, which reflect the party's interests, goals, and perceptions. The dynamics in the set of the objectives is a function of the change in the negotiation conditions (knowledge, information, relationship, proposals and other). Another assumption is that for each party, the set of the objectives is finite and constant for a particular iteration of the negotiation process, but it may change in any or all of its aspects at the next iteration. The next sections provide a formal presentation of the objectives model.

<u>a. Quantitative objectives:</u>

Let $D_j^i = [min_j^i, max_j^i]$ be the intervals of the values for quantitative objective $\boldsymbol{j}$ acceptable by party $\boldsymbol{i}$. There exists a scoring function for each objective $\boldsymbol{D_j^i : X_j^i \rightarrow [0,1]}$ that represents the score which party $\boldsymbol{i}$ assigns to the value of objective $\boldsymbol{j}$, in the range of its acceptable values. The score actually reflects how 'good' or 'bad' different values of a quantitative objective actually are, from the perspective of party $\boldsymbol{i}$. The notion of a score here informally means the *utility* of the objective's value, and the scoring function is the *utility function* for that objective. The scores are normalized to the interval [0,1]. Examples of utility functions for quantitative criteria are given in Figure 4.6.

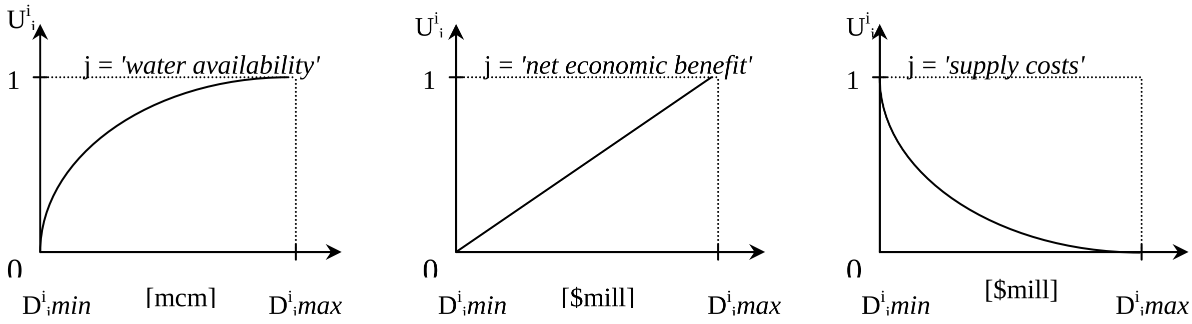

Figure 4.6: Examples of utility functions for quantitative objectives of party *i*. U^i_j and D^i_j are the utility value and the value of objective *j* for party *i*, respectively.

b. Qualitative objectives

Qualitative objectives do not have interval values. Still, different solutions to the allocation problem reflect positively or negatively on each of the qualitative objectives. A utility function, U^i_j, assigns a value from the interval [0,1] to an alternative solution and, similarly to the scoring function of a quantitative objective, reflects the *level of satisfaction* of party ***i*** by that solution, with respect to qualitative criterion (objective) ***j***.

The IDS model admits that the set of the criteria (objectives) of a party may change during the negotiation procedure. It also allows the utility function of a criterion to change as a function of the change in the negotiation conditions. The AHP method, which supports a dynamic change in the structure of the decision problem and assists in dealing with both quantitative and qualitative objectives, is selected as a suitable and practical method for generating the utility functions. According to this method, the utility function of an objective is evaluated in the consequence (outcome) space, which contains the alternatives that are currently 'on the table'. It does not have to be evaluated over the whole interval of the possible values of the objective. Discrete utility values for the alternatives, with respect to a single individual negotiation objective, are obtained in the following way (the detailed explanation and the rationale of the AHP method is given in Section 3.1.5.1):

Let $\boldsymbol{a_1,\ldots,a_k,\ldots,a_L}$ be the set of the alternatives at a certain stage (iteration) of the negotiation process, and $\boldsymbol{o^i_j}$ an objective in the set of current objectives of party ***i*** (recall: the set of objectives, as well as their weights may change between iterations). In order to obtain the weights (scores) that reflect the 'performance' of the ***L*** alternatives with respect to objective $\boldsymbol{o^i_j}$, the party performs pair-wise comparisons. The matrix of comparisons is:

	a_1	a_2	…	a_L
a_1	1	$k^i_j(a_1,a_2)$	…	$k^i_j(a_1,a_L)$
a_2	$k^i_j(a_2,a_1)$	1		$k^i_j(a_2,a_L)$
…	…	…	1	…
a_L	$k^i_j(a_L,a_1)$	$k^i_j(a_L,a_2)$	…	1

Figure 4.7: AHP matrix of comparisons of the alternatives; Comparison according to objective $\boldsymbol{o_j}$ of party *i*. $k^i_j(a_k,a_l)$ is the ratio of the relative weights of two alternatives, $\boldsymbol{a_k}$ and $\boldsymbol{a_l}$, according to objective *j* of party *i*.

$k^i_j(a_k,a_l)$ is the ratio of the relative weights assigned to the two alternatives $\boldsymbol{(a_k, a_l)}$. The score represents the strength of party ***i***'s preference of alternative $\boldsymbol{a_k}$ over alternative $\boldsymbol{a_l}$, with respect to objective $\boldsymbol{o^i_j}$, using the AHP scale of scores: from 1 (equal) to 9 (the first dominates the second) and from 1 (equal) to 1/9 (the second dominates the first). Party ***i***, as the decision-maker, has to fill in only the upper triangle of the matrix of comparisons, since the values in the lower triangle are their reciprocals: $k^i_j(a_l,a_k) = 1/k^i_j(a_k,a_l)$. The utility vales of the alternatives, with respect to this particular objective, are obtained as the components of the principal eigen-vector of the comparison matrix are the weights given to each item in the list of compared items.

4.3.1.2 Overall utility function

The final output of the IDS model, provided to a party in negotiation iteration, are the overall utility values assigned to every alternative in the set of alternatives tabled at that iteration.

The AHP method uses a linear, additive overall utility function (see 3.1.5.1). Alternative $\boldsymbol{a}$ can be represented by a $\boldsymbol{n}$-dimensional vector in the individual consequence space of party $\boldsymbol{i}$: $\underline{\boldsymbol{u}} = [u_1(a),\ldots,u_n(a)]$ where $u_j(a)$ is the score of alternative $\boldsymbol{a}$ with respect to objective o^i_j, $j = 1,..,n$. The utility function defined over the individual consequence space of party $\boldsymbol{i}$ is given as:

$$U_i(a) = w_i^1 u_i^1(a) + w_i^2 u_i^2(a) + \ldots + w_i^n u_i^n(a) \qquad (4.3.1)$$

$$U_i(a) = \sum_{j=1}^{n} w_i^j u_i^j \qquad (4.3.2)$$

Where $w_i^{\,j}$ is the weight, or the relative importance of objective $\boldsymbol{j}$ to party $\boldsymbol{i}$. The weights $w_i^{\,j}$, $j = 1,\ldots,n$, are obtained by the same procedure, using a similar AHP-matrix of pair wise comparisons among the objectives, $c^{\,i}(o_{j1},o_{j2})$, where $j_1 = 1,\ldots,n$ and $j_2 = 1,\ldots,n$ (Figure 4.8).

	o^i_1	o^i_2	…	o^i_n
o^i_1	1	$c^i_j(o_1,o_2)$	…	$c^i_j(o_1,o_n)$
o^i_2	$c^i_j(o_2,o_1)$	1		$c^i_j(o_2,o_n)$
…	…	…	1	…
o^i_n	$c^i_j(o_n,o_1)$	$c^i_j(o_n,o_2)$	…	1

Figure 4.8: AHP matrix of comparisons of the objectives of party *i*. $c^i(o_{j1},o_{j2})$ is the ratio of the relative importance of two individual objectives, o_{j1} and o_{j2}, for party *i*.

Entry $c^i(o_{j1},o_{j2})$ is the result of the pair wise comparison and represents the ratio of the importance of objectives o_{j1} and o_{j2} to party $\boldsymbol{i}$. The IDS model calculates the weights of the objectives as the normalized elements of the principal eigenvectors of the matrix: $\sum_{j=1}^{n} w_j^i = 1$ for $i \in \{ A,B \}$, (as explained in 3.1.5.1).

4.3.1.3 Manipulation of the set of the objectives

If J^t is the set of the objectives in iteration t ($J^t = \{j_1,\ldots,j_n\}$), and J-J^t is the set of objectives that are not being used at iteration *t*, then the manipulation of the set of objectives is defined by two operations: *add* and *remove*.

When a party adds a new objective to the current set, all the weights have to be recomputed. The computational mechanism demands from the party to perform the pair wise comparison of the new objective with the rest of the objectives from the set. Let $c_1, \ldots, c_n$ be the scores from the AHP scale of scores (9 to 1/9) by which the party expresses how much he prefers the new objective over the others. Then, the non-normalized weight of this new objective is:

$$W_{n+1} = \frac{1}{\sqrt{1/c_1^2 + \ldots + 1/c_n^2 + 1}} \qquad (4.3.3)$$

The new, non-normalized weights of the 'old' objectives are:

$$W_i = \frac{W_{n+1}}{c_i} \quad i = 1,\ldots,n \qquad (4.3.3)$$

If objective j_j is removed from the set of the objectives, then the new, non-normalized weights of the remaining objectives are calculated by:

$$W_i = W_i' \sqrt{1 + \frac{W_j^2}{\sum_i W_i^2}}, \quad i \neq j \qquad (4.3.4)$$

where W_i' is the 'old', non-normalized weight of objective *i*.

In both operations, the final weights of the objectives from the new set are normalized by: $w_i = \frac{W_i}{\sum_{i=1}^{n} W_i}$ $\quad i = 1,\ldots,n$, with *n* being the new number of the objectives.

4.3.2 Iterative manner of negotiations

Definitions from 4.3.1 are the basis for the following assumption incorporated into the design of the NSS:

For given negotiation conditions, a "state of the world", and a set of L alternative solutions, party i, $i = \{A,B\}$, can be characterized by a (subjective) utility function, U_i which assigns a single score to every n-tupple $[u_i^1(a_l),\ldots,u_i^n(a_l)]$, $l = 1,\ldots,L$, where n is the number of the party's objectives**.** This score is a real number on the interval [0,1], which expresses the level of overall satisfaction of party i accorded to each of the L alternatives.

The dynamic evolution in the set of the alternative solutions can be shown by movements in the joint consequence space (Figure 4.9). The NSS is designed to assist the parties in advancing towards solutions which (jointly) improve their overall satisfaction.

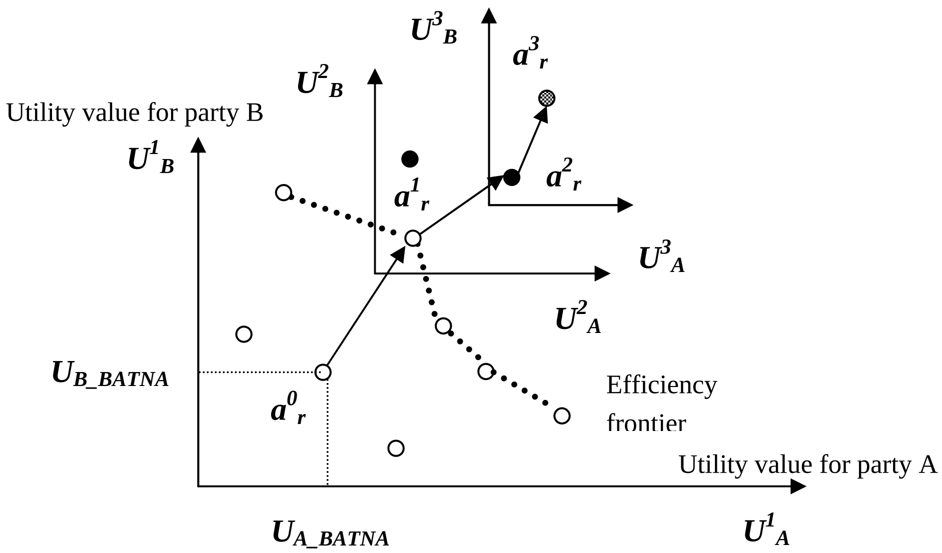

Figure 4.9: Iterative manner of the negotiation process. U^t_A and U^t_B are utility values for parties *A* and *B* in negotiation iteration *t*. U_{A_BATNA} and U_{B_BATNA} are the reservation values of the two parties; a^t_r is the reference alternative in iteration *t*.

The utility function, as a measure of a party's overall satisfaction, is formulated based on that party's preference structure. The NSS allows the parties to change their systems of preferences, in response to changes in the negotiation conditions and, when this occurs, the utility functions also change. Stages of the negotiation process in which the negotiation conditions are constant are called iterations. In Figure 4.2, U^t_A and U^t_B are subjective utility functions of the negotiating parties ***A*** and ***B***, in negotiation iteration t.

In each iteration, the parties negotiate over a set of the alternatives with the aim of (eventually) selecting a single alternative as "the best", according to a previously agreed upon criteria (Section 4.3.2.1). The alternative selected as the "best" in one iteration becomes the *reference alternative solution* for the next iteration. This means that alternatives considered in iteration t are compared relative to one another, as well as to the reference solution selected as "the best" in iteration $t-1$. In a general case, utility scores of a reference solution selected in iteration $t-1$ calculated by U^{t-1}_A and U^{t-1}_B will be different from the utility scores of that same solution in iteration t, calculated by U^t_A and U^t_B, since the preference structure is allowed to change. The reference alternative of the first iteration is the "no agreement" alternative, with utilities U_{A_BATNA} and U_{B_BATNA}, where "BATNA" stands for "the best alternative to negotiation agreement" (see Section 3.2.2). If no alternative in iteration t has a better performance than the reference solution a_r^{t-1}, then this will be the final negotiation resolution.

4.3.3 Joint decision support

When parties have opposed interests, the solution, which maximizes the utility function of one party, will be unacceptable by the other. A negotiation agreement will be achieved only if the parties manage to find a jointly acceptable solution. Within the framework of the NSS, a Game Theory model is included, which assists the parties in selecting an efficient and equitable alternative, among the set of known, feasible alternative solutions to the negotiated problem.

4.3.3.1 Selection of the reference alternative

Selection of the "best" alternative in a single negotiation iteration is performed by accounting for the utility functions of both parties. Once the parties have evaluated their utility functions for a given set of negotiation alternatives, their individual overall rankings can be presented in a joint utility space, as shown in Figure 4.2 as well as in Figure 3.2.1 in Chapter 3.

The NSS utilizes the Nash bargaining solution as the criterion for selection of the efficient and most equitable negotiation resolution. According to Nash (1950), the best alternative in iteration t will be the one which belongs to the efficient frontier and maximizes the product $U^t_A(a)\cdot U^t_B(a)$. Of course, in order to apply this model to a particular negotiation situation, the negotiating parties have to accept the model's basic assumptions regarding the *efficiency* of the solution, as well as the *symmetry* and *equity* among the parties, explained in details in Section 1.3. The translation of preferences into utility values is supposed to create a situation in which the preferences of the two parties are commensurable. I added this sentence; please see whether you agree. Other solution concepts can be applied instead the Nash bargaining model, as long as it is jointly acceptable by both parties.

4.3.3.3 Optimal weights of the objectives

For a given alternative a, which is supposed to challenge the stability of the last reference alternative a_r, the parties are allowed to 'relax' the weights of their objectives, by assigning an upper and a lower limit to the weight of each objective. The final weights of the objectives are then obtained by applying a maximization procedure to the Nash bargaining model, as follows.

Let w^i_A, $i = 1,\ldots,n$ and w^j_B, $j = 1,\ldots,m$, be the weights of the objectives of the two parties in iteration t. Next, let u^i_A and u^j_B, $i = 1,\ldots,n$ and $j = 1,..,m$, be the scores of alternative a with respect to n objectives of party A and m objectives of party B. Then, the product of the overall utilities of the two parties resulting from alternative a is:

$$U_A(a)\cdot U_B(a) = (w^1_A u^1_A(a) + \ldots + w^n_A u^n_A(a))\cdot(w^1_B u^1_B(a) + \ldots + w^m_B u^m_B(a))$$

or, in vector-matrix form:

$$U_A(a)\cdot U_B(a) = \frac{1}{2}w^T C_1 w, \quad C_1 = \begin{bmatrix} 0 & C \\ C^T & 0 \end{bmatrix} \tag{4.3.5}$$

where ***w*** is the row-vector of weights of the two parties, $\left[w_A^1 \ldots w_A^n, w_B^1 \ldots w_B^m\right]$, and ***C*** is the matrix obtained by multiplication of the vectors of the scores of alternative ***a***:

The search fort the optimal weights of the objectives of the both parties is the following quadratic maximization problem:

$$\underset{w}{Max}\frac{1}{2}w^T C_1 w \tag{4.3.6}$$

Subject to the following constraints:

(1) $$w_{A\,min}^i \le w_A^i \le w_{A\,max}^i, \ i = 1,...,n \tag{4.3.7}$$

$$w_{B\,min}^j \le w_B^j \le w_{B\,max}^j, \ i = 1,...,m \tag{4.3.8}$$

Where the limits on the weights have been provided by the parties as the accepted range.

(2) The weights of the objectives of each party sum up to 1:

$$\sum_{i=1}^{n} w_{Ai}^i = 1; \ \sum_{i=1}^{m} w_B^j = 1 \tag{4.3.9}$$

(3) The overall utility of a party is greater than or equal to the utility of that party assured by the previous contract (the last reference alternative):

$$\begin{bmatrix} U_A^T(a) & 0 \\ 0 & U_B^T(a) \end{bmatrix} \ge \begin{bmatrix} U_A^{Ref}(a) \\ U_B^{Ref}(a) \end{bmatrix} \tag{4.3.10}$$

If there is a feasible solution to this optimization problem, then alternative ***a*** will become the new reference alternative, and in case there are no new proposed alternatives, it will be the final negotiation resolution.

4.4 Summary

The basic principles and components of the Negotiation Support System were presented in this chapter. The protocol of interaction prescribes an iterative manner of negotiation which combines individual and joint decision making. Iterations are aimed to support a dynamic relation to the negotiation problem, and to provide the conditions for a gradual improvement of the parties' positions. Each iteration is characterized by (1) the parties' reservation values (BATNAs), (2) a set of feasible alternatives, and, (3) sets of the parties' individual negotiation objectives. Individual decision support utilizes the AHP method and assists the parties to re-evaluate their preference systems and the set of their individual negotiation objectives, from one iteration to another. Generation and evaluation of alternatives is supported by the WAS model, by which the parties can analyze the consequences of various domestic and/or regional water allocation scenarios. In each negotiation iteration, the parties generate (create) alternatives either individually (non-cooperative alternatives) or jointly (cooperative, alternatives). Within the NSS, a private and a public domain for evaluation of the alternatives are distinguished. Publicly, each alternative represents a bundle of two items: the quantity of the allocated water and the economic value of the alternative. Privately, the alternatives are evaluated in terms of individual utility functions. Individual decision support assumes that the parties act as maximizers of their individual utility functions. Joint decision support applies *efficiency*, *symmetry*, and *equity* as the basic criteria for the selection of "the best" alternative, given a set of the negotiation alternatives. The iterative manner of negotiations terminates when there are no (recognizable) feasible alternatives that can challenge the alternative selected as "the best" in the last negotiation iteration.

Algorithms based on the approaches explained in this Chapter are framed in a software application written in Visual Basic (Microsoft Visual Studio.Net) and Matlab (The MathWorks, Inc.) programming languages, aimed for the use in the experimental evaluation of the NSS.

Chapter 5

Experimental evaluation of the Negotiation Support System

5.1 Introduction

The experimental evaluation of the NSS is designed to test the basic premise of the thesis, that the use of the system improves the process and the outcome of negotiations over international water resources. The experiments reported here are exploratory studies, in which *general* hypotheses are formed that state the underlying assumptions about some causal factors. Experiments are then conducted by creating a simulation "laboratory" that generates data, the observation of which either supports or refutes these general hypotheses (Cohen, 1995).

The experimental evaluation includes the following elements (some conducted in parallel, and/or iteratively between the different elements):

1. Definition of a set of propositions that define the negotiations and their outcomes, which are to be tested by the experiments. The basic assumptions regarding the quality of the negotiation process performed with the NSS system and its outcome are expressed through these propositions. Each of them relates to a specific feature of the negotiation process, such as quality of interaction, cooperation, exchange of information, etc.

2. Design of the simulation experiments. Simulated negotiations can be performed in *experiments with real actors* in which selected participants "play" a negotiation game (exercise) based on a case study. An additional way to evaluate the NSS is by *exercise with simulated actors,* which is based partly on inputs provided by the participants, and partly conducted by the researcher.

3. Design of the content and format of the data to be collected from the experiments, and definition of the measures for quantification and analysis of the results.

4. Design of the case study – a hypothetical dispute over international water resources.

5. Selection of the participants, conducting the simulations, recording of data.

6. Interpretation and analysis of the results.

The assumptions and propositions and the basic approach to the experimental design are presented in sections 5.1 and 5.2, respectively. Sections 5.3 and 5.4 detail the logistics, the methodology, and the results of the experiments, while section 5.5 gives an overall summary of the experimental valuation of the NSS.

5.2 Basic assumptions and propositions

The propositions are formulated as a *comparison* between negotiations with the NSS to negotiations without the NSS.

1. *When using the NSS the parties are more creative in searching for alternative negotiation resolutions.*

The assumption here is that the use of the NSS expands the space of possible negotiation resolutions in two ways. First, the facility of exploring a richer set of options by performing sensitivity analysis with the WAS model. By changing the values of the model's parameters that relate to allocations, infrastructure, and national and international water policies, a WAS user can access a range of water allocation solutions which would not be easily recognized otherwise. Second, the AHP method enables decision-makers to define their objectives in an explicit way and to assign their importance (weights). Thus the differences in preferences assigned by each party to his objectives and between the parties become clearer and more obvious, and the opportunity for trade-off between objectives is more easily recognized.

2. When using the NSS, the parties exchange more information.

It has been recognized that negotiators who ask the other party for information about their interests, or who provide information about their own interests, make more accurate judgments and earn higher payoffs (Thompson and Hastie, 1990). While brainstorming and exploring new solutions with the assistance of the WAS model, the parties have the opportunity to recognize the advantages of exchanging information, such as present and expected domestic circumstances and problems related to water management. Their individual preference structure, organized by the individual decision support tool (AHP), provides the basis for a more accurate judgment about the levels of importance and confidentiality of various data.

3. When using the NSS, the parties interact in a more cooperative manner.

When two parties who have a long history of mutual hostilities negotiate, the advantages of cooperation and cooperative solutions are often overlooked because the negotiators' target is victory and not necessarily an efficient and mutually agreed solution. One of the assumptions of the research is that the use of the NSS encourages the parties to be motivated by the goal of utility maximization. The tools of the proposed NSS, including the WAS, are supposed to guide them toward cooperative solutions, which result in higher utility scores to both parties.

4. When using the NSS, the parties are able to define their system of preferences more clearly.

This proposition relates to the following assumptions:

4.1 A party which uses the NSS, has a clearer picture about what are his negotiation objectives, what is the relative importance of each objective, and how much he prefers one negotiation alternative to another;

4.2 A party which uses the NSS relates to his set of the negotiation objectives in a more *dynamic* manner: he adds relevant and/or removes non-relevant objectives during the negotiation process, and has a greater propensity to adapt and changes the relative importance of his objectives.

5. *The agreed negotiation resolution (when one is reached) is economically more efficient than in the case of negotiations without the use of the NSS.*

The underlying assumption here is that the WAS model, as part of the NSS, helps the negotiators to recognize the objective value of the economic criteria, and the opportunity for enlarging the value at stake. We assume that once provided, the information about the economic outcome of proposed allocation schemes will not be ignored, and that the parties will search for solutions that not only meet all other relevant criteria in the best possible way, but are economically efficient as well. In other words, the economic analysis reduces the risk of "leaving potential gains on the table" (Raiffa, 1982).

6. *NSS users are more likely to achieve a higher level of general satisfaction from the agreed negotiation resolution.*

This proposition rests on the following assumptions:

6.1 The use of the NSS tools expands the negotiation (resolution) space and offers the opportunity to reach a solution that will result in higher utility scores for both parties.

6.2 The iterative nature of the negotiation process, aided by the NSS, contributes to maximization of the utility scores. If there is a new iteration, it means that some or all of the following have occurred: new options are added to the resolution space, new objectives are added to the set of objectives, the less valued objectives are traded for those that are valued more. These procedures are supposed to ‘move’ the Pareto frontier of the resolution space in the “Northeast direction” of increased utility scores for both parties.

5.3 Two types of experiments

Two types of experiments were conducted to test the value of the NSS. In *experiments with real actors* (ERA), participants act out the negotiation process, half of them aided by the NSS and the other half without the NSS. Differences in the values of the relevant experimental variables obtained by these two groups are observed and analyzed. *Exercises with simulated actors* (ESA) are conducted by the experimenter (in our case the researcher herself), using certain (subjective) information elicited from the participants. ESA are a type of *exploratory studies,* in which experimental variables can either be *independent* or *dependent* (Cohen, 1995). Independent variables are defined as those whose values are under the control of the experimenter. Dependent variables, in turn, are defined as those variables whose values are not under the control of the experimenter. Instead, the values of these are observed by the experimenter as measurements.

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5.3.1 Experiments with real actors (ERA)

In experiments with real actors the candidates are given the necessary background and instructions about their role as a party to the negotiation. The negotiation process and its outcome are then driven by the players alone. These experiments are performed to test the effect of the use of the NSS on the negotiation process and its outcome. The Test Group negotiates using the NSS, while the Control Group does it without the NSS. The results of the two groups are analyzed and compared.

ERA can be *paired* or *independent*. In *paired* experiments the same candidates take part in the two groups of exercises (with and without the NSS). This is designed to supposedly neutralize the effects of individual inclinations and skills, such as propensity to negotiation, computer literacy, and other skills that could influence the outcome. However, this is impossible to achieve, since the order in which the two experiments are taken has an influence. A participant who first negotiates with the NSS takes with him this experience to the exercise in which he negotiates without the NSS, and would behave differently if his first experience is to negotiate without the NSS and only later with it. There seems to be no way to get around these difficulties, except that some experimental designs may be better than others. We surmise that the better order would be to negotiate first without the NSS, which would be the more "natural" situation, and only then with the NSS, which creates the new negotiating environment.

In *independent* experiments each candidate negotiates either without or with the NSS, not both. Conducting the experiments in this fashion is easier, as each candidate has to spend less time in the exercise. Because we used subjects who were either rather busy and/or did not have sufficient patience to sit for long hours, we had to resort to *independent* experiments. In this mode, the effects of individual factors represent an additional component of experimental error. Randomizing the selection of candidates for experiments with and without NSS is a way to minimize these effects, provided the sample of candidates is large (which unfortunately was not our case). There was an attempt to select the participants from populations, which were uniform with respect to some general or specific individual characteristics, as explained further below.

5.3.2 Exercises with simulated actors (ESA)

Exercises with simulated actors are simulations of negotiations with the NSS, conducted by me, while using certain subjective information provided by the participants. Obviously, these experiments relate only to negotiations with the NSS. The objectives and the initial preference structures are elicited from the participants, while I controlled all further steps of the process. ESA are actually artificial exercises whose aim is to show the potential negotiation outcomes resulting from different subjective inputs of the participants, which represent their (subjective) values and preferences. Negotiation outcomes are a function of the way in which the NSS, with all his components, is used with the subjective inputs of the participants. These artificial exercises show in a step-by-step manner the capabilities and functions of the

NSS. Alternative negotiation solutions are created by the researcher who casts himself in the role of both negotiating parties and a mediator. When needed, the researcher himself contributes with his "subjective" input, fitted to the framework (objectives, limits) of the preference structure given by the participants. The results and outcomes of such simulations are presented in a descriptive and analytical form.

5.4 Experiments with real actors

5.4.1 Participants

Two populations were selected from which it was logistically possible and theoretically justified to recruit candidates for the experiments with real actors. It was assumed that some of the skills relevant for the negotiation exercise, as well as the motivation of candidates to participate in the simulations, were uniform over each of these two populations.

The first group consisted of teachers and trainers in courses on negotiation and mediation at the Israeli Center for Negotiation and Mediation (http://www.icn.org.il). They come from various backgrounds, have varied experience of teaching and coaching in courses, and are practicing mediators.

The second group were engineering students at the Technion, studying towards a BSc or MSc in various fields. Participation in the experiment was in response to a call for volunteers, and each participant was paid for a four-hour session.

5.4.2 Case study

The negotiation game played in the simulation exercises was based on the same hypothetical situation: two neighboring countries, Alfa and Batia, who share a long history of disagreements and mutual mistrust, claim rights to a common water resource. The case studies in the two series of exercises, though based on the same basic idea, differed in the level of complexity of the presented problem and in the amount of information available to the negotiators. The complete case study, and the general and confidential instructions to the participants in the simulations, are given in Appendix 5.I (in Hebrew).

5.4.3 Simulation exercises: design and logistics

The six propositions stated in 5.2 were tested by comparing the results from the simulations performed with and without the NSS. In simulations with the NSS, the quality of the negotiation outcome, expressed by the utility values and net economic benefits it brings to the negotiating parties, is calculated during the negotiation process. In simulations without the NSS, the quality of the outcome is obtained in a post-simulation analysis: the utility value is obtained by the AHP model, based on the subjective inputs of the participants, while the net economic benefit is calculated by the WAS model, by the researcher.

Simulation exercises included three phases. In the first, pre-negotiation (preparation) phase, the participants were given the case study and the general and confidential information, which they read and studied individually, in order to become familiar with the role they were to play. The second phase was the simulated negotiation game. In the third phase, the participants answered the post-simulation questionnaire, and those who took part in the simulations without the NSS, also analyzed their preference structure by the AHP. For both groups, the simulation exercises had to be designed to fit various logistic constraints. The exercises with and without the support of the NSS differed only in the second phase: the participants who negotiated with the model, were instructed to interact according to the steps prescribed by the protocol of interaction dictated by the model. Those who did not use the NSS, negotiated in an unstructured and free manner.

The two series of simulation exercises (with the two groups of participants, the *mediators* and the *students*) were conducted at different stages of the research and model development. The conclusions drawn from the first series of exercises led to improvement and further development of the model’s components.

In the first series of simulations, with the mediators, the NSS consisted of two components, the WAS and the AHP models, combined within a simple protocol of interaction. This version of interaction protocol consisted of general rules, which specified the basic elements of interaction (Figure 5.1). In the second series of simulations, with the students, the NSS was shaped as presented in Chapter 4.

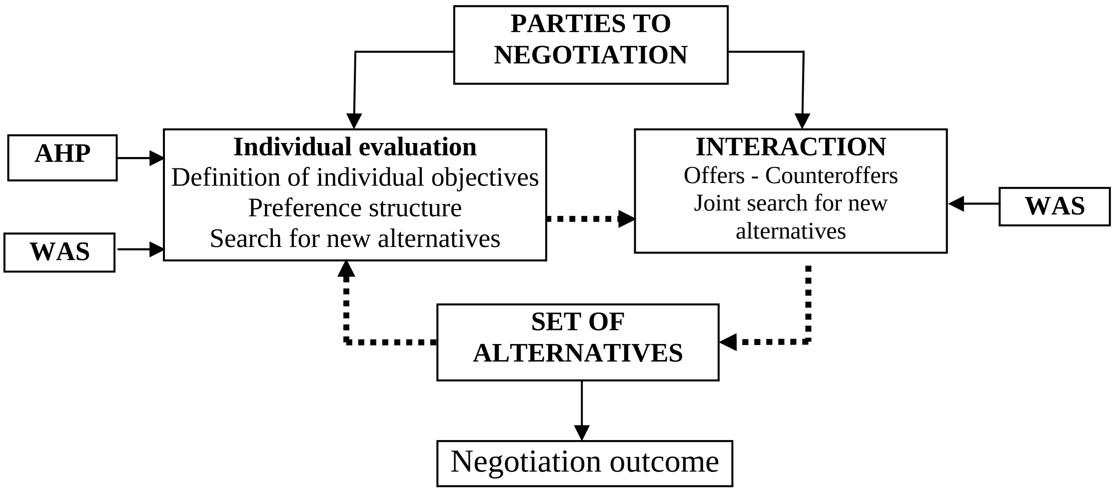

Figure 5.1: Protocol of interaction in the first series of simulation exercises (mediators).

5.4.3.1 Group I: Mediators

Twelve participants, teachers and coaches in courses on negotiation and mediation and practicing mediators from the Israel Center for Negotiation and Mediation (http://www.icn.com) participated in the first group of simulation exercises. All the simulations were performed simultaneously, during a workshop which lasted five hours. At the beginning of the workshop, the participants were given a half-hour lecture/explanation about the economic value of water as well as the principles of the WAS model, and another half-hour lecture about the AHP model. Then, they were randomly grouped into six pairs, three of which performed the simulation with the NSS while three other pairs performed the simulation without it. The exercise itself lasted four hours, including half-an-hour for the negotiation preparation-phase during which the participants read the case study and general and confidential instructions, and another half-an-hour for the post-simulation evaluation. The participants in the simulations with the support of the NSS were not trained to run the model by themselves. Instead, they were assisted during the game by two "technicians" who performed the analysis by the NSS for them (the same two technicians gave this service to all three pairs). The three pairs that played the negotiation game without the support of the NSS analyzed their preference structure by the AHP model in the post-simulation evaluation phase. All participants completed the post-simulation questionnaire.

5.4.3.2 Group II: Students

Altogether twenty-four students participated in the second series of simulation exercises. The exercises were conducted, one per day, in a four-hour session for negotiations without the NSS and a five-hour session for negotiations with the NSS. In both cases, I took records and assisted the participants in handling the NS system (as a “neutral technician”). In the simulations with the NSS, the participants were given the explanation about the economic value of water, individual and group decision support methods embedded in the NSS, as well as the instructions regarding the use of the NSS. In both types of exercises, the simulation game lasted three and a half hours, including the thirty minutes for reading and understanding the case study. In the last half-an-hour of the session, the participants completed the questionnaire, and those who did not negotiate with the NSS, analyzed their preference structure by the AHP model.

5.4.4 Measures

The following explains the methodology for analysis of the data collected by the experiments with real actors.

5.4.4.1 Qualitative measure – post-simulation questionnaire

The questionnaire consisted of twenty statements (items), which related to various characteristics of the negotiation process. Once the exercise ended, the participants were asked to express the extent to which they agree or disagree with each statement. The statements were formulated to elicit an answer on a five-level Likert scale: *strongly agree*, *agree*, *neither agree nor disagree (undecided)*, *disagree,* and *strongly disagree*. A fragment of the questionnaire is shown in Figure 5.2 (in English), while the full questionnaire is presented in Appendix 5.II (in Hebrew).

For each of the statements below, please indicate the extent of your agreement or disagreement by placing a tick in the appropriate column.	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Economic information was most important during the negotiations					
Economic information served as a basis for cooperation					

Figure 5.2: A fragment from the post-simulation questionnaire.

The twenty statements are composed so that they can be grouped into six sets which relate to six attributes (features) of the negotiation process: 1) availability and value of data on economic costs and benefits related to different alternative negotiation solutions, as provided by the WAS model, 2) negotiators' clarity about their individual preference structure, 3) dynamics in their individual preference structures, 4) the level of information exchange during the negotiations, 5) the level of creativity in searching for alternative negotiation solutions, and, 6) cooperative manner of interaction. Some of the statements belong to more than one group. For example, a statement on the level of information exchange can also be a measure of the quality of cooperation. The six sets of statements and their abbreviations (used in the analysis) are given in Table 5.1.

The results of the questionnaire were analyzed *via* the numerical values assigned to categorical responses: 1 and 2 for "strongly agree" and "agree", 3 for "undecided", and 4 and 5 for "disagree" and "strongly disagree".

Generally, the phenomenon being studied by a questionnaire (in our case, the "phenomenon" is a particular feature of the negotiation process), can be measured by a single- or by a multiple-statement scale (Gliem and Gliem, 2003). A single-statement scale represents a variable whose values are the direct responses of the participants to a single statement. A multiple-statement scale is a variable whose values are obtained by averaging (or summing up) the responses of each participant over the set of statements which constitute the scale. A set of statements can constitute a scale if the answers to these statements have a satisfyingly high *Cronbach's Alpha* value (DeVellis, 1991). The explanation of Cronbach's Alpha (AC) is given below.

Table 5.1: Statements of the questionnaire arranged into sets, each relating to a specific feature of the negotiation process

1.	**EC Role of economic data in the negotiation process**
1.1	Your opening arguments were based on economic data
1.2	You relied on economic data from the very beginning of the process
1.3	During the negotiation process your negotiating arguments were based on economic data
1.4	Economic information was most important during the negotiations
1.5	Economic information served as a basis for cooperation
1.6	Economic data helped in creating new alternative negotiation solutions
1.7	Economic data helped in creating new cooperative solutions
1.8	Other information rather than economic was more important
1.9	Importance of economic information increased during the negotiations
1.10	Importance of economic information decreased during the negotiations
2.	**ORDER Clarity regarding individual system of preferences**
2.1	You had a clear picture regarding your criteria (objectives) for accepting and rejecting offered alternative solutions
2.2	You could clearly distinguish offered alternative solutions and say how much you preferred one relative to other(s)
1.3	You could clearly say how much you preferred one negotiation criterion (objective) to another
3.	**CHANGE Dynamics in the set of the objectives**
3.1	You changed the set of objectives during the negotiations
3.2	Relative importance of your objectives changed during the negotiations
4.	**INFO Exchange of information**
4.1	You freely discussed with your opponent your objectives and how important they were to you
4.2	The level of information exchange was high
5.	**CREAT Creativity**
5.1	The set of alternative negotiation solutions significantly changed during the negotiations
5.2	The level of creativity was high
6.	**COOP Cooperative manner of interaction**
6.1	The level of cooperation was high
6.2	The level of creativity was high
6.3	The level of information exchange was high

Cronbach's Alpha (AC)

Cronbach's Alpha is used to test internal consistency of the responses to a questionnaire, and as a justification for the use of multiple-item scales (*item* = statement, question). For a set of N items, it is calculated as:

$$AC = \frac{N \cdot \bar{r}}{1+(N-1)\cdot \bar{r}} \qquad (5.4.1)$$

where $\bar{r}$ is the mean of the inter-item correlation coefficients. The correlation coefficient, r, measures the relationship between two data sets that are scaled to be independent of the unit of measurement (i.e., scaled to the same range); it is calculated as the covariance of two data sets divided by the product of their standard deviations:

$$r_{X,Y} = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y}, \quad \text{where:} \qquad (5.4.2)$$

$$cov(X,Y) = \frac{1}{N}\sum(x_i - \bar{x})(y_i - \bar{y}), \text{ and } \sigma_X^2 = \frac{1}{N}\sum(x_i - \bar{x})^2 \qquad (5.4.3)$$

The closer AC is to 1, the higher is the consistency of the N items. According to De Vellis (1991), a value below 0.6 is considered unacceptable, while Gliem and Gliem (2003) state that values greater than 0.7 are high enough to justify the use of the items as a multiple-item scale.

In our analysis, the following rule was applied: if Cronbach's Alpha (AC) for a particular set of statements is high enough (higher than 0.6), the responses of each participant are averaged over that set so that a single value ("the average response") is obtained for each participant. The negotiation feature (attribute) addressed by this set of statements is, then, represented by a single "explanatory variable". For example, the responses of the mediators to the three statements which relate to the quality of cooperation have an AC value of 0.78, so that they constitute a single (three-statement) scale, COOP. On the other hand, if the statements in a set had an unacceptably low AC value, they were re-arranged into subsets, which have a sufficiently high AC. If some statements could not improve the AC value of any subset, they were analyzed individually, as single-statement measures. In cases where the original set of statements had to be broken into several subsets (and/or single statements), the corresponding attribute of the negotiation process is perceived as being composed of a number of (not necessarily correlated) sub-attributes, and is analyzed *via* more than one explanatory variable. For example, the responses of the mediators to all ten statements which relate to the role of the economic data in the negotiation process produced a low AC value (0.54). The set was broken into two

two-statement subsets (with AC values of 0.94 and 0.7), and four single statements, so that the role of the economic data is analyzed by six explanatory variables[1].

The participants' attitude towards the NSS is analyzed in the following way: the values of each explanatory variable obtained by the participants who negotiated with the NSS are compared to the values obtained by the participants who negotiated without the NSS. The comparison is performed by applying a *two-stage nested linear model* to each explanatory variable.

Two-stage nested (hierarchical) linear model

Nested (hierarchical) models belong to the family of statistical techniques used for analysis of the effects of several factors (conditions) on some particular phenomenon (also referred to as *multi-factor analysis*). The *phenomenon* here is a particular explanatory variable (single or multiple-statement variable). There are two factors: the first divides the participants into two groups (two levels): those who negotiated with the NSS and those who negotiated without it. The second relates to the fact that each participant belongs to a particular pair of negotiators (the number of levels of this factor equals the number of pairs). Pairs and groups can be represented by the nested (hierarchical) layout in Figure 5.3.

[1] Various authors differ on the term "consistency", and to what Cronbach's Alpha actually measures. According to the definition stated in the SPSS Manual (**SPSS Manual, UCLA Academic Technology Services: http://www.ats.ucla.edu/stat/spss/faq/alpha.html**), *it measures how well a number of items describe a single, one-dimensional variable*. According to Bernstein (1995: **Bernstein, I.H.: Web-correspondence:http://www.math.yorku.ca/Who/Faculty/Monette/Ed- stat/0219.html**), a high value of AC does not mean that the set of items is one-dimensional: a set can consist of two types of items which correlate highly among their respective subsets, and the set as a whole would have a high AC, even if the correlations among the items from different subsets were not high. He argues that *Cronbach's Alpha measures the extent to which item responses correlate highly*. In our analysis, Bernstein's definition is adopted for the following reason: the statements in the post-simulation questionnaire were composed and grouped into sets according to negotiation features which were to be tested, without a specific aim to make these sets one-dimensional or necessarily consistent with respect to these features. This means that the participants were not expected to be consistent among themselves: one could have agreed with all the statements of a particular set, while another could have agreed with some, and disagreed with the rest of the statements of the same set.

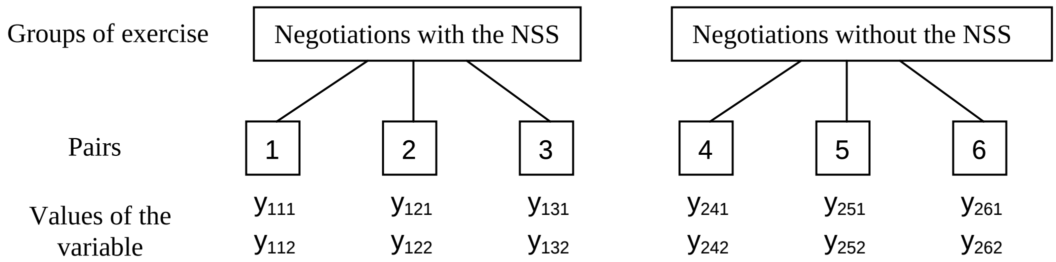

Figure 5.3: Layout of a nested hierarchical model for the values of a single variable, obtained from the responses of twelve participants who negotiated in six pairs: three with the NSS and three without.

The model is used to test whether the fact that the participants negotiated in a particular group and pair affected their answers to the post-simulation questionnaire.

The linear model for the two-factor nested design is:

$$y_{ijk} = \mu + \tau_i + \beta_{j(i)} + \varepsilon_{(ij)k} \qquad \begin{cases} i = 1,2 \\ j = 1,2,...,n \\ k = 1,2 \end{cases} \tag{5.4.4}$$

where y_{ijk} is the *response variable* of the model, that is, the value of the explanatory variable in case of candidate who negotiated as party k, in negotiating pair j, in group i. Index i indicates the negotiations with or without the NSS; index k can have values 1 or 2 since the negotiations are bilateral; n is the number of pairs; μ is the mean value of the variable over all $2n$ participants, τ_i is the effect of the first factor (group i), β_j is the effect of the second factor (pair), and $\varepsilon_{(ij)k}$ is a random error term.

The significance of the two factors (groups and pairs) is tested by conducting an analysis of variance (by the F-test) for the all terms in the model (Montgomery,1997). This analysis tests the hypothesis that all the parameters, for an individual factor (τ_i, $i = 1,2$ for groups and, β_j, $j = 1,..,n$, for pairs), are zero.

Statistical analysis of the responses to the post-simulation questionnaire was performed with *JMP, A Business Unit of SAS, Version 4.* The results are presented in section 5.3.5.

5.4.4.2 Quantitative measures - negotiation outcome

Two quantitative variables were used to assess the quality of the negotiation outcome: *individual overall utilities* and *net economic benefit,* achieved in the final negotiation resolution. Participants who negotiated without the NSS evaluated their preference systems and utility values by the AHP method during the post-simulation phase. Economic net benefits were calculated a-*posteriori* also, by the researcher. The idea was to assess the quality of the negotiation by a statistical comparison of 1) individual overall utilities achieved by the negotiation resolution and the individual *Status Quo* utilities (the *Status Quo* utility of a party indicates the level of his satisfaction by the situation without the negotiations, or, in case the negotiations are broken), 2) individual and joint net economic benefits from water use, achieved in the negotiation resolution, and those assured by the *Status Quo* scenarios (without the negotiations, or in case the negotiations are broken). Since the number of the participants in each group (mediators, students) was too small for a proper statistical analysis, the results are only presented and discussed in section 5.4.6.

5.4.5 Results of the post-simulation questionnaire

In both series of simulations, the participants had difficulties in using the NSS system Nevertheless, in the case of the first series of simulations, with the mediators, both types of exercises (with and without the NSS) were completed as planned: one half of the participants negotiated with the NSS, and the other half without. The answers of the two groups (denoted as W/NSS and WO/NSS, respectively) are statistically compared (explained in 5.4.4.1) and the results are presented below. In the second series of simulations, with the students, exercises with the NSS were not successful (because of time and other logistic limitations) and are therefore excluded from the analysis. Still, analysis of the students' responses to the post-simulation questionnaire showed some differences in the answers of those who reached agreement and those who did not. Therefore, the statistical procedure (explained in 5.4.4.1) was applied to the responses of the students (eighteen participants in nine pairs, all negotiated without the NSS), in order to elicit what particular features of the negotiation process, as perceived by the participants, affected the negotiation outcome. Throughout the following presentation of the results, the students who reached an agreement are denoted as W/AGREE while those who did not as WO/AGREE.

A summary of the statistical analysis of the responses to the post-simulation questionnaire is presented in Tables 5.2 and 5.3. Variables whose values were calculated as the average over some or all of the statements from the corresponding set are denoted "multiple measures", while variables which represent single statements are denoted "single measures". A Nested Linear Regression (NLR) model is applied to the values of each variable, and the F-test is used to examine whether there is a significant difference between a) the responses of the participants in two main groups: "effect NSS" (W/NSS versus WO/NSS) for the mediators, and "effect agreement" (W/AGREE versus WO/AGREE) for the students, and b) between the responses of the participants who negotiated in different pairs ("effect pair"). A "plus" ("+") in the "effect" columns indicates the significance of the difference in the answers between the groups (or among pairs) relative to a p-value of 0.05. Each variable is represented by its mean value, calculated over the two groups, and by the frequency, according to the number of "observations" falling in one of the three aggregated Likert categories: "Agree" (A), "Undecided" (U), "Disagree" (D).

The responses in the post-simulation questionnaire are analyzed with respect to five features of the negotiation process: individual system of preferences, level of creativity, exchange of information, cooperative manner of interaction, and relevance of economic data.

5.4.5.1. Mediators – statistical analysis of the responses to the questionnaire

A. Individual system of preferences. According to the F-test for the NLR model applied to the values of variable ORDER, there is a significant difference between the participants who used the NSS (W/NSS) and those who did not (WO/NSS) regarding the clarity about their individual systems of preferences. This relates to use of the AHP model, which deals with the objectives and preferences. The corresponding values of ORDER, averaged over the two groups, are 2.1 and 3.9, respectively, showing that **the participants who used the AHP model agree that they had a "clear" picture about the set of their preference structure during the negotiations, while those who did not use it, do not agree**.

The analysis of variable CHANGE shows that the opinions regarding the dynamics within the set of individual negotiation objectives are statistically similar over the two groups. The average values of CHANGE are close to 3, corresponding to "undecided" on the Likert scale. The original responses of the participants (before averaging), show that **four participants who used the AHP model, and only one of those who did not use it, agree that they changed the set of objectives during the negotiations. The same four participants form the first group, while three participants from the second group changed the *relative importance* of their objectives.**

B. Level of creativity. The F-test for the NLR model applied to the responses to the average of the two statements on the level of creativity (CREAT), shows that the effect of the NSS tools was not significant: **all the participants agree that the set of alternatives was enlarged and that creativity in searching for alternative solutions was at a high level during the negotiations.** Values of CREAT, averaged over the two main groups of mediators, are 2.1, in simulations with the NSS tools, and 2.2 in simulations without the NSS tools.

Table 5.2: Summary of the answers to the post-simulation questionnaire - Mediators

Variable	Type of measure	Statement No.	AC Value	Mediators									
				Effect model	Effect pair	Mean I*	Frequency***			Mean II**	Frequency***		
							A	U	D		A	U	D
ORDER	Multiple	11,12,14	0.86	+	-	**2.1**	5	1	0	**3.9**	0	2	4
CHANGE	Multiple	16,17	0.83	-	+	**2.8**	4	0	2	**3.1**	3	1	2
CREAT	Multiple	15,19	0.65	-	-	**2.1**	6	0	0	**2.2**	5	1	0
COOP	Multiple	18,19,20	0.78	-	-	**1.4**	6	0	0	**2.1**	4	3	0
INFO	Multiple	13,20	0.31	-	-	**1.5**	6	0	0	**1.9**	6	0	0
EC	Multiple	1,2,3,4,5,6, 7,8,9,10	0.54	+	-	**3.1**	1	5	0	**2.5**	4	2	0
	Single	1	-	-	-	**3.8**	0	2	4	**3.7**	0	2	4
	Single	2	-	-	-	**3.5**	1	2	3	**3.8**	1	1	4
	Multiple	3,4	0.94	+	-	**3.7**	1	3	2	**2.3**	6	0	0
	Multiple	6,7	0.70	-	+	**2**	4	2	0	**1.6**	6	0	0
	Single	5	-	-	-	**2.3**	4	0	2	**1.8**	5	1	0

* Value of the variable averaged over the group of participants who used the NSS (six participants)

** Value of the variable averaged over the group of participants who did not use the NSS (six participants)

*** Frequency of the variable according to ranges: [1, 2.5] = "**A**gree", (2.5, 3.5] = "**U**ndecided", (3.5, 5] = "**D**isagree"

C. Exchange of information. Analysis of the values of INFO shows that **all participants believe they shared information effectively** (1.5 and 1.9 are the average values of INFO for groups W/NSS and WO/NSS, respectively).

D. Cooperative manner of interaction. The F-test for the NLR model applied to the averaged responses proved that there is no significant difference between the responses of the participants in the two main groups (the average values of COOP are 1.4, among those who used the NSS, and 2.1 among those who negotiated without it). **On the average, all participants believe that the interaction between the negotiating parties was conducted in a cooperative manner**.

E. Relevance of economic data. The Alpha Cronbach (AC) value for all ten statements on the relevance of economic information during the negotiations is relatively low (AC = 0.54; see section 5.3.4.1 for the explanation about the acceptable values of AC). The NLR model applied to the average values of all ten responses shows that there is a significant difference between the two main groups of the participants. The W/NSS participants are, on the average, undecided regarding the relevance of economic data (with an average response of 3.1), while the WO/NSS participants agree more than disagree that the economic data did represent relevant information (with an average response of 2.5). A better insight into the opinion of the mediators regarding the availability of economic information is obtained when grouping the EC statements into sub-sets according to high AC values, and also by analyzing a few relevant statements individually. According to the results, the original responses to the two statements on *the importance of economic information at the very beginning of the negotiations* (statements No. 1 and 2), are statistically similar between the participants of the two groups: **none of the twelve participants explicitly agree that they based their opening arguments on economic information; only two participants are certain they relied on the economic information from the beginning of the negotiation process.** Responses to statements No. 3 and 4, *on the importance of economic information throughout the negotiation process*, are analyzed *via* the average responses of the participants (Alpha Cronbach value for these two statements is 0.94). Here, the difference in the responses of the two groups is proven to be statistically significant. **Those from W/NSS, who**

had the opportunity to use the WAS model, do not think, on the average, that the economic information was important: two participants explicitly state it was not, three are "undecided", while only one believes that the economic information was important during the negotiation process (the average response for this group is 3.7). **All six participants from WO/NSS who were dealing only with data regarding water supply costs, believe that the economic information was important** (the average response for this group is 2.3).

According to the subset of two statements, No. 6 and 7, and statement No. 5, analyzed individually, **all participants, without a significant difference between the W/NSS and WO/NSS groups, believe that the economic information improved creativity in searching for new negotiation resolutions, and provided a basis for cooperation** (the average values for these two measures are 2 and 2.3 for those who used the NSS, and 1.6 and 1.8, for those who did not).

According to these results, it seems there is inconsistency in the responses of the participants who used the WAS, relating to the three EC variables: they do not think that economic information was important during the negotiations, but they do believe, on average, that it improved creativity and cooperation. A detailed examination of the original individual responses (before averaging), as well as written records taken by the participants during or immediately after the session, shows the following: four of the six participants who used the WAS model think that economic information helped in searching for new non-cooperative and cooperative alternatives, while two do not think so or are undecided. All three pairs in this group reached an agreement which included a side payment. The size of side payments was, in all three cases, proportional to water supply costs. From this it can be concluded that 1) the participants who used the WAS model, did not utilize the information about the economic benefits but did use the data on supply costs, 2) the term "economic data" in the statements of the questionnaire, related to two types of information (costs and benefits), and this caused the four participants to give contradictory answers: they related to data on *water supply costs* when stating that "economic information" assisted in creativity and cooperation, and to *net economic benefits from water use*, when stating that "economic information" was not important during the negotiation process.

5.4.5.2 Mediators - summary of the results of the statistical analysis

a. The AHP model assisted the negotiators in constructing and understanding their individual system of preferences. Those who used the model had a clearly defined set of criteria according to which they accepted or rejected alternatives. They also believe they could determine the relative importance of the objectives. Those who did not use the AHP model did not have a clearly defined set of criteria.

b. Regarding the dynamics within individual system of preferences, the participants in both groups differ in their opinions: some think that they consciously changed some of their criteria and/or the relative importance of these criteria during the negotiations, while others do not think so. The opinion of those who used the AHP model is not significantly different from those who did not use it. This can be explained by the lack of sufficient time for the exercise - the AHP method was used only once, at the beginning of the negotiation process, and could not affect the dynamics in the set of individual objectives.

c. All participants, without any significant difference between the W/NSS and WO/NSS group, believe that they freely shared information, were creative in searching for new negotiation alternatives, and negotiated in a cooperative manner. As trained mediators, the participants knew what are the benefits of cooperative negotiations, and were, most probably, pre-disposed to negotiate in this manner. Even if the level of creativity, information sharing, and cooperation was not high, in an objective sense, the participants were, nevertheless, persuaded that they put all their effort to be cooperative and achieve a jointly beneficial solution.

d. The statements of the questionnaire, on the availability of economic information during the negotiations, were found to be ambiguous. They related to both the information about water supply costs, which was available to all participants, and the information regarding the economic benefits from water use, which was available only to those who used the NSS tools. Nevertheless, based on the responses to all ten statements, the following conclusions can be drawn:

- None of the participants based their opening arguments on economic information. At the very beginning of the negotiations, the participants chose to rely on other information and objectives, rather than economic, since they did not have the opportunity to recognize it's potential (for both enlarging the space of alternative solutions and achieving joint economic benefits). At some point of the negotiation process they found themselves "locked" within their opposing arguments, and unable to advance toward a jointly satisfying solution. Here, they started looking for new possibilities and involved economic considerations.

- All the participants felt comfortable with the information about *water supply costs*: it was clearly presented, easy to understand and manipulate (calculate). Those who were supposed to utilize the data about the *net economic benefits* of alternative negotiation solutions (W/NSS) probably did not fully understand the meaning of this information, which is not too familiar to people without background in economics.

5.4.5.3. Students – statistical analysis of the responses to the questionnaire

A. Individual system of preferences. A very low AC value (0.1) was obtained for the set of three statements which define the variable ORDER, so each statement is analyzed separately. **The participants in the W/AGREE pairs (those who reached a negotiated solution) feel that they had a clear view about of their individual objectives** (the average over this group is 2.1), **while the WO/AGREE pairs (those who did not reach an agreement) do not share this view** (with an average response of 3.8). The significance of the difference between the two groups is proven by the F-test applied to the NLR model for this statement.

Responses of the participants from the two groups to the other two statements (No. 12 and 14) are statistically similar. The average response to the statement on the relative importance of their objectives calculated for all eighteen participants is 3.9, implying that, **on the average, they could not tell how much each objective was important relative to others**. The average response of all participants to the statement on the clarity regarding the relative "goodness" of the alternatives is 3: **seven participants believe they could tell how much they preferred one alternative solution to another, while eleven could not tell or are undecided regarding this issue.**

Dynamics in the set of individual objectives (CHANGE): AC value for the set of the two statements is negative. Nested linear regression models, applied to each of the two statements separately, show that there is no significant difference between the answers of the participants in the W/AGREE and WO/AGREE groups. **None of the participants changed the set of the objectives during the simulation (with 4.1 as the average response for all eighteen participants). Six participants agree with the statement that the importance of (some of) the objectives changed during the negotiations while thirteen others do not agree, or are undecided (with 3 as the average response).**

B. Level of creativity. The participants, on average, agree that the level of creativity during the negotiations was high. Value of CREAT, averaged over the whole group is 2.7 (of all eighteen participants, nine believe that creativity was high, six do not believe so, and three are undecided).

C. Exchange of information. Here, too, there is no significant difference in the values of INFO between the two groups of the participants (the average score for W/AGREE is 2.8 and for WO/AGREE is 3.0). Out of all eighteen participants, seven believe they freely discussed their objectives and preferences with their counterpart and that the level of information exchange was high, while the rest do not believe, or are undecided.

D. Cooperative manner of interaction. The results of the analysis of the responses to the three statements which describe the manner of interaction between the negotiators show that that there is a significant difference between the answers of the participants in the two groups. The average values of the COOP are 2.6, for W/AGREE, and 3.4 for WO/AGREE. **On the average, the participants who reached an agreement agree more than disagree with the statement that the interaction with their counterpart was conducted in a cooperative manner** (out of

Table 5.3: Summary of the answers to the post-simulation questionnaire - Students

Variable	Type of measure	Statement No.	AC Value	Students									
				Effect agreem.	Effect pair	Mean I*	Frequency*** A	Frequency*** U	Frequency*** D	Mean II**	Frequency*** A	Frequency*** U	Frequency*** D
ORDER	Single	11	_	+	-	**2.1**	8	2	0	**3.8**	0	3	5
	Single	12	_	-	+	**2.8**	5	3	2	**3.3**	2	3	3
	Single	14	_	-	-	**4**	1	1	8	**3.8**	0	3	5
CHANGE	Single	16		-	-	**4.1**	0	1	9	**4**	0	1	7
	Single	17	–	-	-	**3.1**	2	5	3	**2.9**	4	0	4
CREAT	Multiple	15,19	0.81	-	+	**2.8**	5	2	3	**2.6**	4	1	3
COOP	Multiple	18,19,20	0.59	+	+	**2.6**	5	2	3	**3.4**	0	4	4
INFO	Multiple	13,20	0.67	-	-	**2.8**	5	3	2	**3**	4	0	4
EC	Multiple	1,2,3,4,5,6, 7,8,9,10	0.64	-	-	**2.4**	7	3	0	**2.4**	5	3	0
	Single	6	_	-	-	**2.4**	6	2	2	**1.5**	8	0	0
	Single	7	_	+	+	**1.7**	8	2	0	**2.5**	0	3	5
	Single	5	_	+	-	**1.8**	9	1	0	**3.5**	0	2	6

* Value of variable averaged over participants in the pairs that reached the agreement (ten participants)

** Value of variable averaged over participants in the pairs that did not reach the agreement (eight participants)

*** Frequency of the variable according to ranges: [1, 2.5] = "**A**gree", (2.5, 3.5] = "**U**ndecided", (3.5, 5] = "**D**isagree" ten participants, five believe that cooperation and creativity were on a high level, and four believe that the exchange of information was intensive). **Those who did not reach an agreement do not believe, on average, that their interaction was cooperative** (out of eight participants, none believes that the level of cooperation was high, four agree with the statement that creativity was on a high level, and three believe that the information exchange was intensive).

E. Relevance of economic data. The participants, on average, believe that the economic information was important during the negotiation process. There is no significant difference between the opinions within the two main groups (the average values of EC for all eighteen participants is 2.4).

Alpha Cronbach for the set of the statements on the *assistance of the economic information to creativity in searching for new alternative solutions* (No. 6 and 7), is negative, implying that the responses of the participants to these two statements are not directly correlated. Nevertheless, the analysis of the responses by NLR models applied to each statement individually, and the corresponding F-tests, shows that, for both statements, there is no statistically significant difference between the opinion of the participants in the two main groups (W/AGREE and WO/AGREE). **On the average, all of them believe that the economic information assisted in searching for cooperative and non-cooperative alternative solutions** (thirteen explicitly believe, while five others are undecided).

Responses to the statements on economic information as a basis for cooperation were significantly different between the two groups (W/AGREE and WO/AGREE). **The participants who reached an agreement believe that the economic data provided a basis for cooperation, while those who did not reach agreement, do not believe so** (with average responses of 1.8 and 3.5, respectively).

5.4.5.4 Students – - summary of the results of the statistical analysis

Even though the series of simulations with the students did not provide a basis for exploring the effects of the NSS, some relevant conclusions can be drawn from these exercises:

a. *A high level of clarity and self-confidence regarding individual preference structure can provide a good basis for reaching an agreement:* the participants in the W/AGREE pairs believe they had their negotiation objectives well defined, while the participants in the WO/AGREE could not tell what exactly are their objectives during the negotiations.

b. *Providing the negotiating parties with opportunities and conditions for cooperation increases the chances that they will reach an agreement:* according to the subjective opinion of the participants in the W/AGREE pairs, the level of the cooperation was high.

c. *Economic considerations in water allocation problems are an attractive way of enlarging the "cake"*: four out of five reached agreements that include trade in water; in three out of four that ended without an agreement, still trade in water was proposed as an alternative.

5.4.6 Quantitative analysis of the negotiation outcome

Utility values of the negotiation alternatives considered during the simulated negotiations, and the economic gains achieved by the negotiation outcomes are given in Tables 5.4 to 5.7: A and B stand for the parties; Alternative 1 is the "Status Quo", i.e. the original division of water between the parties (which can also be labeled "Break off", since this would be the result if the negotiations failed, i.e., were "broken off") while 2 and 3 were created by the parties during the negotiations. “Nash” stands for the Nash product of the individual utilities; the alternatives which maximize the Nash values are indicated by **bold font**. The alternative selected by the parties as their agreed final solution is indicated by grey background**.**

Economic gain to a party is calculated as the difference between the net economic values of water to that party according to the Status Quo alternative and according to final negotiation outcome. The maximum possible joint gain to the two parties is $238 million, which results when the disputed water resource is treated as a *common pool*, with the allocation of 48 and 52 percent to the two parties (see Section 3.3.3 for explanation of the *common pool* alternative).

5.4.6.1 Mediators

In the first series of simulations, with the Mediators, the pairs considered up to three alternative negotiation solutions, including the *Status Quo* alternative. Five of the six pairs reached an agreement. Four of these five pairs agreed on the alternative which maximized the Nash product of the individual utilities (without being aware of it while they were negotiating): two pairs from W/NSS, and two from WO/NSS. Since the Nash algorithm was not included in the NSS used in these simulations, the fact

Table 5.4: Utility values of negotiated alternatives – Mediators (grey: agreed alternative; bold: negotiation alternative which maximizes the Nash value).

	Alternative solution	**Pair I**			**Pair II**			**Pair III**		
		U(A)	U(B)	Nash	U(A)	U(B)	Nash	U(A)	U(B)	Nash
Neg. without the NSS	1 (Status Quo)	0.47	0.08	0.04	0.12	0.16	0.02	0.71	0.17	0.12
	2	**0.68**	**1.0**	**0.68**	**0.94**	**1.0**	**0.94**	0.56	0.54	0.30
	3	0.92	0.24	0.22	0.36	0.59	0.21	**0.47**	**1.0**	**0.47**
	Alternative solution	**Pair IV**			**Pair V**			**Pair VI**		
		U(A)	U(B)	Nash	U(A)	U(B)	Nash	U(A)	U(B)	Nash
Neg. with the NSS	1 (Status Quo)	0.34	0.25	0.09	0.76	0.24	0.18	0.16	0.18	0.03
	2	0.55	0.87	0.47	**0.49**	**0.67**	**0.33**	**1.0**	**1.0**	**1.0**
	3	**0.75**	**0.79**	**0.59**	0.40	0.70	0.28	-	-	-

Table 5.5: Net economic gains achieved by the negotiation outcome - Mediators

Individual and joint economic gain achieved by the agreement (m$)*									
	Pair I			Pair II			Pair III		
Negotiations without the NSS	A	B	Joint	A	B	Joint	A	B	Joint
	118	-122	-4	53	100	153	0	0	0
	Pair IV			Pair V			Pair VI		
Negotiations with the NSS	A	B	Joint	A	B	Joint	A	B	Joint
	66	12	78	54	59	113	132	74	206

*Maximum possible joint economic gain = 238 m$

that the pairs selected the Nash-optimal alternatives is not related to the "effect NSS". It can be seen as an indication that, according to the majority of the participants in these simulations, the *Nash solution* corresponds to the concept of a "fair" solution.

The pair that did not reach an agreement negotiated without the NSS (Table 5.4, Pair III). A post-simulation analysis of their preference structures (by the AHP model), showed that the two other alternatives considered during the negotiations would increase the utility value of one party (B: from 0.17 to 0.54 or even 1.0), but decrease the utility of the other (A: from 0.71 to 0.56 or 0.47).

Individual and joint net economic gains achieved by the negotiation outcome are shown in Table 5.5. The six exercises in this series are not enough to draw any general conclusion regarding the value of the NSS in achieving economically efficient agreements (the participants' difficulties in use of the NSS were explained in the previous section). Nevertheless, it can be seen that all three pairs who negotiated with the NSS, agreed upon a solution that brought positive economic benefits to both parties, which is not the case for the WO/NSS group of pairs.

5.4.6.2 Students

In the second series of simulations, with the Students (all negotiated without the NSS), the pairs considered up to six alternative solutions, including the *Status Quo* alternative ("Break off"). Five of the nine pairs reached an agreement. A post-simulation analysis (by the AHP model) showed that four of these five pairs agreed upon the alternative which maximized the product of their utilities ("Nash", Table 5.6a).

Of the pairs who did not reach an agreement (Table 5.6b), only one (Pair III) confirmed, in the post-simulation evaluation of individual preference structures, that breaking off the negotiations was the preferred alternative to both parties. For the other three pairs, at least one alternative (other than the "break off" alternative) was preferred by at least one of the parties; at least one other of these alternative had a Nash product higher than the "break off" alternative. It is thought that poor communication between the parties in negotiating without the NSS prevents them from understanding the advantages of other alternatives: such effects could have been recognized only by analyzing the alternatives within a *joint utility space*.

Table 5.6a: Utility values of negotiated alternatives – Students who reached an agreement (grey: agreed outcome; bold: alternative which maximizes the Nash value)

Alternative Solution	**Pair V**			**Pair VI**			**Pair VII**		
	U_A	U_B	Nash	U_A	U_B	Nash	U_A	U_B	Nash
1 (Status Quo)	0.09	0.95	0.09	0.24	0.23	0.06	0.11	0.27	0.03
2	0.89	0.32	0.28	**0.88**	**0.37**	**0.32**	0.16	0.99	0.16
3	**0.75**	**0.48**	**0.36**	0.23	0.76	0.17	0.95	0.14	0.13
4	**0.62**	**0.58**	**0.36**	0.35	0.49	0.17	**0.66**	**0.52**	**0.34**
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-

Table 5.6a (continued): Utility values of negotiated alternatives – Students who reached an agreement

Alternative solution	**Pair VIII**			**Pair IX**		
	U_A	U_B	Nash	U_A	U_B	Nash
1 (Status Quo)	0.15	0.47	0.07	0.09	0.94	0.09
2	0.15	0.51	0.08	0.18	0.32	0.06
3	0.19	0.58	0.11	**1.0**	**0.27**	**0.27**
4	0.60	0.45	0.27	-	-	-
5	0.76	0.51	0.39	-	-	-
6	**0.99**	**0.53**	**0.52**	-	-	-

*** BATNA = Best Alternative to Negotiation Agreement**

Table 5.6b: Utility values of negotiated alternatives – Students who did not reach an agreement

Alternative solution	**Pair I**			**Pair II**			**Pair III**			**Pair IV**		
	U_A	U_B	Nash	U_A	U_B	Nash	U_A	U_B	Nash	U_A	U_B	Nash
1 (Status Quo)	0.10	0.77	0.08	0.12	0.81	0.10	**0.83**	**0.86**	**0.72**	0.10	0.52	0.05
2	**0.99**	**0.34**	**0.34**	**0.81**	**0.95**	**0.77**	0.43	0.26	0.11	0.06	0.83	0.05
3	0.10	0.32	0.03	0.98	0.26	0.26	0.31	0.49	0.15	**0.78**	**0.33**	**0.26**
4	0.80	0.21	0.17	-	-	-	0.20	0.39	0.08	0.95	0.21	0.20
5	0.33	0.19	0.06	-	-	-	0.23	0.33	0.08	-	-	-
6	0.10	0.14	0.01	-	-	-	0.48	0.34	0.16	-	-	-

Table 5.7 shows individual and joint net economic gains achieved by the negotiation agreements (the gain to parties in pairs who did not reach an agreement is obviously

zero, since the gain is calculated relative to the Status Quo). In all five pairs, the joint gain is negative. These negotiations were performed without the NSS, so that the parties did not have any assistance (in the form of the relevant information, or as a decision support tool like the WAS) in analyzing the economic effects of the negotiated alternatives.

Table 5.7: Net economic gains achieved by the negotiation outcome - Students

Individual and joint net economic gains achieved by the agreement (m$)*														
Pair V			Pair VI			Pair VII			Pair VIII			Pair IX		
A	B	Joint	A	B	Joint	A	B	Joint	A	B	Joint	A	B	Joint
85	-108	-23	-49	-6	-55	58	-82	-24	8	-37	-29	-13	-11	-24

*** Maximum possible joint economic gain = 238 m$**

However, the records taken during the exercises show that four out of five reached agreements included trade in water. In three out of four simulated negotiations that ended without an agreement, trade in water was proposed as an alternative; minimum water supply costs was present as one of the criteria in all four simulations. These data can be seen as a proof that the parties were interested in the economic aspects of the water allocation problem, and that they could have benefited from the NSS.

5.4.7 Experiments with real actors (ERA): summary and conclusions

These simulations with real actors, due to the limitations of execution, cannot be considered a complete evaluation of the Negotiation Support System and its benefits. Still, some observations can explain, at least in part, the results of the simulations:

- The time given to the participants for learning and understanding the principles and components of the NSS, as well as the duration of the negotiation exercise were too short.
- Even within a particular group (students, mediators), the participants greatly differed in their ability to comprehend the functions of the basic NSS components.
- In all simulations, a “technician” (the researcher) was present, whose role was to perform the runs with the WAS model according to instructions from the participants. However, the information provided by the technician was too complex (quantities and value of water, shadow prices) for most of the

participants, so that they did not use it in the expected way, sometimes even ignored it.

- Because of the lack of sufficient time and the difficulties in using the NSS, most of the participants lost their motivation and turned to a "simple bargaining" manner of interaction, ignoring the existence of some or all negotiation support tools;

The time constraint, which was a major cause for these difficulties, was impossible to change for various logistic reasons. One way to improve the efficiency of the experiments could have been design of simulations that would be performed by participants who would meet on several successive occasions for a few hours each time. Between these meetings they would have plenty of time and opportunity to learn and efficiently use all the features of the NSS and explore the effects of a variety of alternative negotiation solutions with the WAS model. In this way, the potential for an iterative negotiation process and a gradual improvement of positions would be better tested.

We can compare this with a case reported in the literature. ICONSnet (http://www/icons.umd.edu) is a Web-based simulation software that has been used for negotiation simulations with real actors. The negotiation exercise are among participants from distant locations (different countries) who communicate through the internet, in several sessions of practically unlimited duration. In our research it was impossible to find participants who would have time or would be motivated for any reason to take part in such prolonged simulations.

Another way to adjust the experiments to these constraints would be simplification of the case study, which was used in the simulations. Some of the negotiation support models described in the literature that were evaluated by experimental simulations, were designed for negotiation processes in which time had a major role (see Chapter 2, negotiations in a hostage crisis, GENIE, Wilkenfeld et al., 1995), or negotiations where the major difficulty was manipulation of a large amount of data (MEDIATOR, Jarke et al., 1987). Such negotiation support systems can be evaluated by experiments based on case studies that are simplified to fit simulation conditions (time constraints, participants' skills, etc). The simplification of the negotiation problem in these cases could still leave all important features of the support system to be activated and tested, and contribution of the negotiation support can be fully explored and evaluated. In our case, simplification of the problem would not allow for testing all features of the proposed NSS. Data that serve as input for the WAS model would have to be reduced and presented in an over-simplified manner. That would reduce also the space (number) of feasible negotiation solutions and give much less opportunity to negotiators to be creative.

Given all these considerations and constraints, the only feasible way to continue the experimental evaluation of the proposed NSS system was to perform "Exercise with Simulated Actors" (ESA, as explained in Section 5.3.2 of this Chapter).

5.5 Exercise with simulated actors (ESA)

In the following exercise, the initial "independent subjective input" regarding the ranks of the parties' negotiation objectives was provided by two particular candidates from the exercise with real actors (ERA). All other subjective considerations of the negotiators as of individual decision makers are performed by the researcher.

5.5.1. Background

Two countries, Alfa and Batia, are negotiating the allocation of a shared water resource – The Aquifer - over which both of them claim rights (see Figure 5.4). The current arrangement between the two countries is the result of previous negotiations: Alfa has ownership and the right to use 20 percent, while Batia has ownership and the right to use 80 percent of the resource. There are other water sources in the region, which are not in dispute between the two countries. The territory of Alfa is divided into two separate parts. Annual renewable quantities of water in all the resources, including the Aquifer, have already been utilized (data about the available water resources in the Region are given in Appendix 5.III). In order to satisfy the high demand for water of its consumers, Batia has been desalinating seawater. Except for expensive seawater desalination, there are no other ways to increase the quantity of water available to the two countries. Both of them are expecting an increase in population in the future and are interested in getting as much as possible of the Aquifer's water. The two countries have a long history of disputes and hostilities, and their relationship suffers from lack of mutual confidence.

Both Alfa and Batia, as well as the "outside world", perceive the negotiations over the disputed Aquifer as an important part of the ongoing overall peace process, aimed at improving the relationship between the two countries. Each country is divided into a number of districts, each represented by three water demand sectors: urban, industry, and agriculture (basic characteristics of the districts and sectors, in terms of WAS input data are given in Appendix 5.III). The map in Figure 5.4 shows the location of sources, demand districts, conveyance system, and the production and conveyance cost. Both countries have access to the Sea.

Alfa's basic concerns

Because of the expected increase in population, it is of crucial importance to Alfa to intensify it's agricultural production. Alfa is less prosperous than Batia, and agriculture is the easiest way to increase its GDP. Intensification of agriculture depends on the availability of additional quantities of water. Seawater desalination is

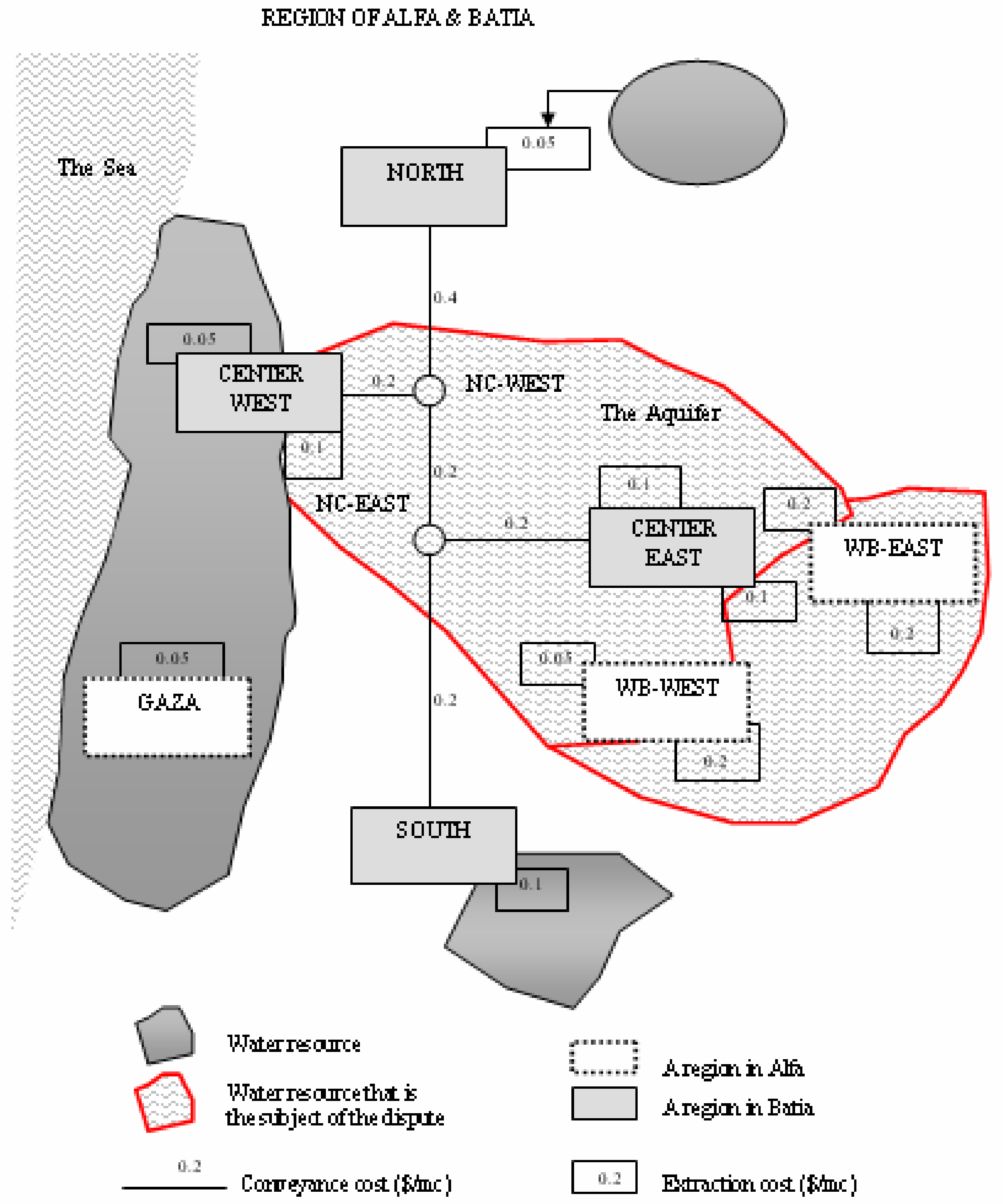

Figure 5.4: The Map of the Region with the disputed countries

too expensive. Alfa is concerned by the economic efficiency of its overall water utilization. The Aquifer is a much cheaper water resource.
About 80 percent of the Aquifer's recharge area is within Alfa's territory, which it uses as the basis to claim rights to more than 20 percent of the Aquifer's waters. Alfa is also aware that only improved relationship with Batia can provide the basic conditions for Alfa's further development. However, until this happens, Alfa prefers to have its water supply independent of Batia.

Batia's basic concerns

Batia is more prosperous than Alfa. About two thirds of its annual water supply is used in agriculture. Intensive agricultural production is important to Batia since, because of the tense relations with its neighbors, it prefers to be independent in food production. Also, agriculture enables keeping the remote parts of the country (along the borders) populated, which is important for strategic reasons. Were it not for these strategic considerations, Batia could allow the agricultural sector to decrease, so that it could be satisfied with about half of the present annual water consumption. However, a significant decrease in the agricultural sector would cause unemployment and, because of the great influence which this sector has on the political scene, would also cause social instability. If agricultural production were decreased, Batia would also need to invest heavily in dealing with the resulting unemployment and upset social stability.

Batia has large expenditures for seawater desalination. Meanwhile, however, there is no other way to cover the difference between the high annual demand for water and the available quantities of water in Batia's natural resources. A decrease in its share in the Aquifer's waters would mean an increase in expensive seawater desalination.

Batia is aware that improving relationship with Alfa would bring many benefits, but until this happens, it prefers to have its water supply independent of Alfa: meanwhile it limits the supply from the disputed Aquifer to its most populated district, Center - West, to 15 mcm/year.

Alfa and Batia's representatives have each established their own independent sets of negotiation objectives which relate to interests at the national and international levels (Table 5.8).

Table 5.8: Negotiation objectives of the two countries

Alpha's objectives	Batia's objectives
1. Increase of the ownership over the shared Aquifer; 2. Economic efficiency of water use - EC; 3. Water supply independent of Batia - IND; 4. Intensification of agricultural production in Alfa -AGR; 5. Improvement of the relationship with Batia - RELAT.	1. Economic efficiency of water use - EC; 2. Independent water supply - IND; 3. Reliable water supply- RELAY; 4. Social stability within the country - SOC; 5. Improvement of the relationship with Alfa - RELAT.

5.5.2. The negotiation process

The negotiation process began in a simple bargaining manner, and has reached the point at which Batia faces the choice between breaking the negotiations or offering to 'give up' additional 20 percent of the resource to Alfa. Giving up 20 percent of the Aquifer means that the final allocation of the rights of use of the Aquifer's water will be 40 and 60 percent to Alfa and Batia, respectively. Alfa's representative has the possibility of responding to this offer by (1) accepting the offer or (2) breaking off the negotiations. These two alternative responses have different consequences regarding the objectives set by Alfa. Breaking off means leaving with the right to only 20 percent of the aquifer, while accepting the offer means getting 40 percent of the aquifer. In order to compare and choose one of them, Alfa has to know what will be the consequences of each alternative. This depends on the way each allocation will be utilized within Alfa. Hence, Alfa first uses the NSS to analyze each of these two alternatives.

5.5.2.1 Alfa's individual consequence (utility) space

Alfa needs a set of criteria for assessment of the value of different 'domestic' scenarios that a specific allocation alternative represents. Assume that this set of criteria includes all of the Alfa's objectives given above, except the one that relates to Alfa's part in the Aquifer. This objective is excluded since all the scenarios resulting from a particular allocation are equally 'good' with respect to this objective. Alfa uses the AHP algorithm to calculate the weights (importance) of the four remaining objectives. These weights are the coefficients of Alfa's utility function according to which the 'best' scenario for each allocation alternative will be selected. Assume that, having performed the AHP process on these four objectives, the representative of Alfa comes up with the following weights:

$$U^{A}(a_i) = 0.424w_i^{EC} + 0.038w_i^{IND} + 0.424w_i^{AGR} + 0.114w_i^{RELAT} \qquad (5.5.1)$$

where a_i stands for domestic scenario i from the set of all domestic scenarios considered by Alfa and $w_i^{\,j}$ is the performance of scenario a_i according to Alfa's negotiation objective j, $j = EC, IND, AGR, RELAT$ (see 3.1.5.1 for the explanation of the AHP model and individual utility functions). The weights mean that he places equal weight on the economic and agriculture objectives, considerably less weight on the relations with Batia, and an almost insignificant weight on independence in water management. These weights are merely for illustration, are subjective values, relevant to a particular negotiator, but in reality they would also reflect the instructions given by the Leader who sent him to negotiate (see Chapter 2 for the explanation about the assumptions regarding to the systems of values of the parties to negotiation).

(1) Accepting the '40-60 percent' allocation of the Aquifer

There are many different possible domestic allocations among the various consumers for using the available water resources within Alfa. These are analyzed with the countrified version of the WAS (Water Allocation System) model. Suppose, first, that Alfa considers the present domestic (fixed-price) water policy, and a free price (or, "unconstrained") policy, which is supposed to bring the largest economic benefit from water use (see Section 3.3 for explanation of these water policies). He would also like to explore the effects of physically connecting the two distinct parts of the country. Therefore, Alfa's first four domestic scenarios are:

A.1 Policy of current prices fixed at 0.15, 0.65, 0.65 $/mc for the agricultural, industrial and urban sectors, respectively, with no physical connection linking the two parts of the country (current water-policy);

A.2 As **A.1**, with a connection between the two parts;

A.3 'Free price' policy – prices charged to consumers will be defined by a 'market' solution, according to the demand and supply functions; no connection between the two parts of the country;

A.4 As **A.3**, with a connection;

Next, Alfa considers the expected increase in population. He can utilize the additional quantity of water to intensify agriculture. A way to encourage agricultural production is to provide a subsidy in the prices charged to agricultural consumers. Another way to deal with the increased population is to set the quantities of water, supplied to each district and each water demand sector, at least equal to the minimum expected future demand for water (Table 5.III.3 in Appendix 5.III). Alfa formulates these alternatives as the following four domestic scenarios:

A.5 Free price policy and a subsidy applied to the prices charged to agricultural consumers, in order to support the farmers and encourage their production (see Chapter 3 for the explanation of the meaning of the subsidy and its influence on the demand function); no connection between the two parts of the country;

A.6 As **A.5**, with a connection;

A.7 Free price policy constrained by the supply to all consumers greater or equal to the expected future demand; no connection between the two parts of the country;

A.8 As **A.7**, with a connection.

Alfa's negotiator analyzes these alternatives with WAS, and uses the output from the WAS model for evaluating the scenarios (Appendix 5III). Alfa decides that alternatives **A.5** and **A.7** are not relevant for further analysis, and uses the AHP model to evaluate the other six alternatives: he measures the *economic efficiency* of the alternatives according to the net economic benefit, and *intensification of agriculture* according to the quantity of water supplied to the agricultural sector. Alfa considers that *independence in water supply* is related to the existence of the conveyance system between the two disconnected parts of the country. The *relations with Batia* are generally better when there is a conveyance system connecting the two parts of the country, and when Alfa does not subsidize the prices charged to agricultural consumers.

Utility values of the alternatives with respect to Alfa's objectives, and their final utility scores for the '40-60' allocation proposal (calculated according to Eq. 5.4.1) are given in Table 5.9.

Table 5.9: Weights of the objectives and utility scores of Alfa's domestic scenarios, in case of the '40-60' allocation

Scenario	Utility values for the scenarios according to the objectives				Overall Utility*
	Economic efficiency ***0.424***	**Independent water supply** ***0.038***	**Intensification of agriculture** ***0.424***	**Relations with Batia** ***0.114***	
A.1	0.16	1.00	0.14	0.30	**0.20**
A.2	0.44	0.33	0.14	0.97	**0.37**
A.3	0.52	1.00	0.07	0.30	**0.32**
A.4	0.59	0.33	0.23	0.87	**0.46**
A.6	1.00	0.33	0.76	1.00	**0.87**
A.8	0.49	0.33	1.00	0.90	**0.75**

* See Section 3.1.5 for the explanation about the AHP model and individual utility functions.

According to the overall utility values, in case Alfa accepts the '40-60' offer, the 'best' scenario (**A.6**) would be to subsidize the prices charged to agricultural consumers and to connect the two distinct parts of Alfa with a water-conveyance system.

(2) Breaking off the negotiations

In case the negotiations are suspended, Alfa's ownership over the aquifer would continue to be 20 percent. Currently (the *Status Quo* alternative), water in Alfa (a total of 216 mcm) is allocated to the consumers according to a fixed-price policy, at 0.15, 0.65, and 0.65 $/mc for agricultural, industrial, and urban uses, respectively. Conveyance of water between the two parts of the country does not exist. Alfa decides to explore other scenarios of domestic water supply for the '20-80' allocation and uses the NSS to examine the same domestic alternatives for water supply as in the case '40-60' allocation.

Table 5.III.6 in Appendix 5.III gives the results of the WAS simulations for alternatives **A.9**, **A.10**, **A.11**, and **A.12**. According to both 'fixed' and 'free' price policies, all the available water in Alfa is consumed. In order to provide the demand required by the 'fixed' price policy, Alfa would have to desalinate seawater (**A.9**, **A.10**). In the '20-80' allocation, the alternatives with a subsidy for prices to agricultural consumers or those which satisfy future demands turn out to be irrelevant, since they could be implemented only by introducing expensive desalination.

Alfa has to select one of the four scenarios for its domestic allocation which will be relevant in case the negotiations are suspended. He performs the analysis by the model for individual decision support and obtains the following ranking of the four alternatives (Table 5.10):

Table 5.10: Utility scores of Alfa's domestic scenarios, in case the negotiation are suspended (the '20-80', or, the *Status Quo* allocation).

	Utility values for the scenarios according to the objectives				
Scenario	**Economic efficiency** ***0.424***	**Independent water supply** ***0.038***	**Intensification of agriculture** ***0.424***	**Relations with Batia** ***0.114***	**Overall utility**
A.9	0.23	1.00	1.00	0.12	**0.57**
A.10	0.56	0.33	1.00	0.32	**0.71**
A.11	1.00	1.00	0.25	0.37	**0.61**
A.12	1.00	0.33	0.25	1.00	**0.66**

According to the final scores, scenario A.2 has the 'best' performance with respect to the set of Alfa's objectives, given the '20-80' allocation, although the difference between it and alternative A.4 is not large.

5.5.2.2 Batia's individual consequence (utility) space

In case Alfa rejects Batia's offer and demands more than 40 percent of the Aquifer, Batia can consider breaking of the negotiations. Hence, Batia's representative has to analyze the consequences of both '40-60' and '20-80' allocations. He sets the following domestic scenarios for consideration:

B.1 The *Status Quo* arrangement. Batia's current water policy uses prices fixed at 0.17, 1, and 1 \$/mc for agricultural, industrial, and domestic consumers, respectively; water supply from the Aquifer to the Center-West District (CW) is limited to 15 mcm;

B.2 As **B.1**, with no limitation on the supply of the Aquifer's water to CW;

B.3 Free price policy – prices charged to consumers will be defined by a market solution, according to the demand and supply functions; supply from the shared Aquifer to Center-West is limited to 15 mcm;

B.4 As **B.3**, with no limitations on the supply of the Aquifer's water to CW;

B.5 Supply of water to each consumer in each district is set equal to the minimum required quantity. Such minimal supply of water affects mostly the agricultural consumers, since it reduces the allocation to agriculture to half of the present consumption; supply from the shared Aquifer to the densely populated area is limited to 15 mcm;

B.6 As **B.5**, with no limitations on the supply of the Aquifer's water to CW;

Batia uses the set of objectives (criteria) which are given in Table 5.8 for assessing of performance of the six scenarios. Using the AHP model he calculates the weights of the objectives and defines the following utility function:

$$U^{B}(a_i) = 0.042w_i^{EC} + 0.335w_i^{IND} + 0.143w_i^{RELAY} + 0.396w_i^{SOC} + 0.084w_i^{RELAT} \quad (5.5.2)$$

where a_i stands for domestic scenario i considered by Batia. The greatest weight is placed on social stability (this can be interpreted as representing the importance placed in Batia on keeping the water allocation to agriculture, which is an influential sector), then on independent water management, with lesser importance placed on reliability and much less on relations with Alfa, and least of all on the economic consequences (again, there is no attempt to claim that these would be real preferences; they are given merely as an example, structured to bring out 'interesting' results).

(1) The '40-60' allocation alternative

If Alfa accepts Batia's offer, Batia can use only 60 percent of the annual renewable quantity of the Aquifer's water. For assessment of the consequences of the six scenarios for domestic water use, this quantity is added to the other water resources available to Batia, and the scenarios are analyzed by the countrified version of WAS (the results are in Table 5.III.7 in Appendix 5.III). Batia's representative analyzes the output of the WAS model and ranks the scenarios using the individual decision support algorithm (AHP). Batia translates the WAS (quantitative) output into the qualities of the scenarios to be judged with respect to the five criteria, in the following way: *reliability* of water supply is judged according to the quantity of desalinated water (desalination is the most "reliable" water resource, since it does not depend on meteorological conditions); *relationship with Alfa* is better in case Batia does not limit the supply of water to the Center-West; the effect of the scenarios on the *social stability* can be evaluated according to the quantity of water allocated to the agricultural sector.

The scores of the scenarios according to each of the five objectives, as well as their final utility, are given in Table 5.11.

Table 5.11: Utility scores of Batia's domestic scenarios, in case of the '40-60' allocation.

Scenario	**Utility values for the scenarios according to the objectives**					**Overall utility**
	Economic Efficiency 0.042	Independent water supply 0.335	Reliable water supply 0.143	Social stability 0.396	Relations with Alfa 0.084	
B.1	0.08	1.00	1.00	1.00	0.13	**0.89**
B.2	0.08	1.00	1.00	1.00	0.61	**0.93**
B.3	0.88	0.49	0.26	0.19	0.50	**0.36**
B.4	1.00	0.12	0.15	0.19	1.00	**0.26**
B.5	0.27	0.29	0.15	0.11	0.43	**0.21**
B.6	0.47	0.31	0.15	0.11	0.91	**0.26**

In case Batia ends up with the right to use only 60 percent of the Aquifer, the best scenario for domestic water supply would be one of the two scenarios based on a fixed-price policy (**B.1** and **B.2**) which have almost the same utility score. However, according to the objective *Relations with Alfa*, the only objective on which these two scenarios differ, scenario **B.2** is definitely "better" than **B.1** which should make it definitely preferable. According to scenario **B.2**, a fixed price policy is implemented and the supply of water from the disputed Aquifer to the Central West district is not limited.

(2) Breaking off the negotiations

If case the negotiations are suspended, the relations between the two countries will be seriously damaged. On the other hand, Batia will remain owner of 80 percent of the

Aquifer's yield. Batia wishes to analyze all possible (relevant) consequences of the '20-80' alternative. First, he considers that domestic scenarios for allocation of water within the country cannot affect the relations with Alfa, once the negotiations are broken. Hence, the objective *Relations with Alfa* is excluded from the set of objectives. Batia uses the AHP, to calculate the new weights of the other four objectives, and obtains the new utility function:

$$U^B(a_i) = 0.035 w_i^{EC} + 0.573 w_i^{IND} + 0.122 w_i^{RELAY} + 0.270 w_i^{SOC} \qquad (5.5.3)$$

Next, Batia performs the WAS runs of the six scenarios for domestic water allocation with 80 percent of the Aquifer's annual yield and uses the results to analyze the consequences (Table 5.III.7 in Appendix 5.III). Then the individual decision support algorithm is used to obtain the scores and final utility values of the scenarios with respect to the four objectives (Table 5.12).

Table 5.12: Utility scores of Batia's domestic scenarios, in case the negotiations are suspended (the '20-80', or, *Status Quo*, allocation).

	Utility values for the scenarios according to the objectives				
Scenario	Economic Efficiency *0.035*	Independent water supply *0.573*	Reliable water supply *0.122*	Social stability *0.270*	**Overall utility**
B.7	0.11	1.00	0.28	1.00	**0.88**
B.8	0.11	0.59	0.28	1.00	**0.65**
B.9	0.40	1.00	0.55	0.35	**0.75**
B.10	1.00	0.19	0.64	0.35	**0.32**
B.11	0.21	1.00	1.00	0.19	**0.75**
B.12	0.58	0.19	1.00	0.19	**0.30**

B.7 turns out to be the best alternative, according to the overall utility score. It is also the "best" alternative according to the two most important objectives to Batia: *Independent water supply* and *Social Stability*.

5.5.2.3 Enlarging the set of alternatives: trade in water

If Alfa accepts the '40-60' allocation, it will not use all 40 percent of the Aquifer's water: according to the results of WAS, it would not be economically justified for Alfa to use all of its allocation (beyond some particular quantity, it would mean supply to consumers at costs higher than their willingness to pay for additional unites of water). One of the parties suggests trade in water. Depending on the 'domestic' scenario Alfa will decide to adopt (see results in Appendix 5.III), there will be between 60 and 143 mcm of the Aquifer's water available for trade (the meaning of the 'ownership' and 'trade' in water is explained in Chapter 3). Alfa's and Batia's negotiators accept the mediator's suggestion as worth pursuing and turn to the NSS to analyze it.

5.5.2.3.1 Alfa's analysis of the ‘trade’ alternative

If Alfa sells to Batia the right to use a certain quantity of water it will, in turn, expect a side-payment from Batia (see Section 3.2.2.1). The exact quantity of water for trade and the actual payment will be the subject of negotiation between the two parties. Alfa estimates the additional benefit by multiplying the whole quantity of water available for trade (different for each of the six domestic scenarios) by a price of 0.5 $/mc. This is half of the assumed maximum price Batia will be willing to pay, which is 1 $/mc (the cost of desalination). Alfa decides that the trade affects only the performance of the domestic scenarios with respect to the objective *Economic Efficiency,* performs a new pair-wise comparison of the scenarios and obtains their scores according to their economic efficiency, as well as their new final cardinal ranks (Table 5.13, with the value without trade taken from Table 5.9). The utility scores of the scenarios relative to other objectives have not change, neither has the relative importance of the objectives. The overall utilities of the six scenarios are calculated by Equation 5.4.1.

Table 5.13: Utility scores of Alfa's ’s domestic scenarios, in case of the ‘40-60’ allocation and trade in water.

Scenario	Utility values		Overall utility without trade	Overall utility with trade
	Economic efficiency without trade *0.424*	*Economic efficiency* with trade *0.424*		
A.1	0.16	0.56	**0.20**	**0.37**
A.2	0.44	1.00	**0.37**	**0.61**
A.3	0.52	1.00	**0.32**	**0.53**
A.4	0.59	0.56	**0.46**	**0.45**
A.6	1.00	0.33	**0.87**	**0.59**
A.8	0.49	0.21	**0.75**	**0.63**

The scenario with the highest final utility value with trade is **A.8 -** the one that assures at least the expected future demand to each consumer (each sector of each district in Alfa), and includes a connection between the two parts of the country. However, increased economic benefit, as the result of the trade, decreases the differences in cardinal ranks of the domestic scenarios: the three best scenarios, **A.2**, **A.6**, and **A.8** have close utility values. In order to get clearer results regarding the 'performance' of each scenario, Alfa goes back to the utilities of the scenarios with respect to each objective (Tables 5.9 and 5.13). Scenarios **A.2** and **A.8** are the best according the two most important Alfa's criteria (*Economic efficiency* (Table 5.13) and *Intensification of agriculture* (Table 9)), and he decides that one of them should be selected. It turns out that scenario **A.2** is better with respect to the criterion *Relationship with Batia*, and therefore, Alfa selects it as the best for the case of a '40-60' allocation and water trade between the parties. This scenario does not increase water supply to Alfa's agricultural sector; however, for the side-payment he can get from Batia, Alfa can desalinate at least 30 mcm of seawater (the minimum traded quantity of water will be 60 mcm, and it is supposed that Alfa does not agree to trade in water for less than a price of 0.5 $/mc).

5.5.2.3.2 Batia's analysis of the 'trade' alternative

If Batia purchases the right to use a certain quantity of the Aquifer's water from Alfa's 40 percent, its total available quantity of water for domestic allocation will increase. The six scenarios for domestic allocation of water will have different consequences than in the case of the '40-60' allocation of the Aquifer without the trade. WAS simulations are performed twice for each scenario: once with 60 mcm and once with 143 mcm – the minimum and the maximum potential quantity of water for trade (the results of the runs are in Table 5.III.8 in Appendix 5.III). In order to obtain an estimate of the size of the side-payment, Batia multiplies the additional quantity of water (60 and 143 mcm) by half of the maximum price Alfa might ask for – which is the cost of desalination ($\$1/m^3$). For each scenario, the estimated payment is subtracted from the net economic benefit given by WAS.

Batia analyzes the final resulting economic benefit and other relevant results of the WAS model, and performs the AHP analysis of the six domestic scenarios with respect to the five objectives (criteria). The relative weights of the objectives are the same as in Equation 5.4.2. Scores of the scenarios and their final utility values are given in Table 5.14.

Table 5.14: Utility scores of Batia's domestic scenarios, in case of the '40-60' allocation and trade in water.

Scenario	Utility values for the scenarios according to the objectives					Overall utility
	Economic Efficiency *0.042*	Independent water supply *0.335*	Reliable water supply *0.143*	Social stability *0.396*	Relations with Alfa *0.084*	
B.1	0.09	1.00	1.00	1.00	0.10	**0.89**
B.2	0.13	0.41	1.00	1.00	0.16	**0.69**
B.3	0.41	1.00	0.32	0.35	0.27	**0.56**
B.4	1.00	0.13	0.14	0.35	0.39	**0.28**
B.5	0.20	1.00	0.14	0.19	0.66	**0.49**
B.6	0.55	0.13	0.14	0.19	1.00	**0.25**

Thus, if Batia purchases water from Alfa, the best scenario for domestic water allocation will be **B.1**, with a fixed price policy and the supply of water from the Aquifer to CW limited to 15 mcm/year.

5.5.2.4. Joint utility space

At this stage, Alfa and Batia have three alternative negotiation solutions:

a. Breaking off the negotiations and remaining with the *Status Quo* ('20-80') allocation;

b. '40-60' allocation of the Aquifer;

c. '40-60' allocation of the Aquifer and trade in water;

The *Status Quo* alternative is the parties' Best Alternative to Negotiation Agreement (BATNA). In terms of the negotiation process as it is modeled by the NSS, it also represents the *Reference Alternative 1*, because it is guaranteed to the negotiating parties.

If one of the other two alternatives is selected as the "best", it will be one candidate alternative for the final negotiation resolution. It will also be the new solution guaranteed to the parties, and its stability as the final negotiation resolution will be challenged in the next round of the negotiation process (it will then be *Reference Alternative 2*).

The three alternatives are publicly represented by the bundles $(Q_{Alfa}(a_i), v_{Alfa}(a_i))$ and $(Q_{Batia}(a_i), v_{Batia}(a_i))$, where $Q_{Alfa}(a_i)$ and $Q_{Batia}(a_i)$ are the allocated quantities of the Aquifer's water to the two parties and $v_{Alfa}(a_i)$ and $v_{Batia}(a_i)$ are the net economic gains to the parties achieved by selecting alternative a_i over the Reference Alternative 1 (see Chapter 4), given in Table 5.15. *Allocated quantities* of the Aquifer's water to the parties are the quantities of water to which the parties have the "right to use". For example, in the '40-60' allocation alternative without trade in water, Alfa has the right to use 40 percent of the Aquifer, even though this quantity is far beyond the demand for water in Alfa; in the '40-60' allocation alternative with trade, Alfa 'sells' Batia the right to use 17 percent of the Aquifer, so that 40-17 = 23 percent is left at Alfa's disposal.

Net economic gain in the third alternative ('40-60' alternative with trade in water) is calculated by assuming that the agreed upon price of a cubic meter of water for trade is

Table 5.15: Allocations and net economic gains achieved by the alternative negotiation solutions in the first round of negotiations

	ALFA		BATIA	
Alternative	Allocation of the disputed Aquifer Mcm (%)	Net economic gain (m$) relative to Ref. Alt. 1	Allocation of the disputed Aquifer (mcm)	Net economic gain (m$) relative to Ref. Alt. 1
a. Ref. Alt. 1 (*Status Quo*)	126 (20%)	0	504 (80%)	0
b. Accept '40-60'	252 (40%)	11	378 (60%)	-118
c. Accept '40-60' and trade	148 (23%)	65	484 (77%)	-64

$0.5, which is half the cost of seawater desalination. In reality, the price is subject to bargaining between the parties.

Each party performs a pair-wise comparison of these three alternatives, with respect to his set of relevant objectives. Alfa adds the objective *Increase in the ownership over the Aquifer* and calculates the weights of the new utility function he will use to evaluate the alternatives within the joint utility space. Batia uses the utility function given in Equation 5.4.2. The results of Alfa's and Batia's individual evaluations of the three negotiation alternatives are given in Tables 5.16 and 5.17. The 'optimal' alternative, according to the considerations and criteria given in Chapters 3 and 4, is the one for which the Nash product of Alfa's and Batia's utilities is maximal. The utility values of the three alternatives and their Nash products are given in the following tables:

Table 5.16: Alfa's utility scores of the alternative negotiation solutions

Alternative	Utility values for the alternatives (ALFA)					Overall utility
	Economic Efficiency *0.4*	Independent water supply *0.05*	Intensification of agriculture *0.39*	Ownership 0.04	Relations with Batia *0.12*	
a. *Status Quo*	0.11	1.00	0.18	0.19	0.13	**0.19**
b. Accept '40-60'	0.26	1.00	1.00	1.00	0.36	**0.62**
c. Accept '40-60' and trade	1.00	1.00	0.35	1.00	1.00	**0.75**

Table 5.17: Batia's utility scores of the alternative negotiation solutions

Alternative	Utility values for the alternatives (BATIA)					Overall utility
	Economic Efficiency *0.04*	Independent water supply *0.34*	Reliable water supply *0.14*	Social stability *0.40*	Relations with Alfa *0.08*	
a. *Status Quo*	1.00	1.00	0.22	1.00	0.11	**0.81**
b. Accept '40-60'	0.25	1.00	1.00	1.00	0.43	**0.70**
c. Accept '40-60' and trade	0.25	1.00	0.572	1.00	1.00	**0.92**

Table 5.18: The Nash products of the utility scores of the alternatives in the first round of negotiations

Alternative	Utility values		The Nash Product
	Alfa	**Batia**	
a. *Status Quo*	0.19	0.81	**0.16**
b. Accept '40-60'	0.62	0.70	**0.44**
c. Accept '40-60' and trade	0.75	0.92	**0.69**

According to the Nash product (Table 5.18), the '40-60' alternative with trade in water is the most fair and therefore, selected as the *Reference Alternative 2*.

5.5.2.5 The second round of negotiations

The mediator (and/or the parties) decides to challenge Reference Alternative 2 with "regional" alternatives, which view the disputed Aquifer as a *common pool* resource. In a "regional" alternative the optimal allocation of the Aquifer to the two parties is determined by the regional version of the WAS model (see Chapter 4).

Additionally to the *common pool* approach, the parties decide to analyze the implementation of free-price policy in both countries, while ensuring the minimum future demand for water to each consumer in each district in Alfa, and at least the minimum required supply of water to each consumer in each district in Batia. Alfa decides not to subsidize agricultural production. Batia decides to keep the supply from the Aquifer to the Central West district limited to 15 mcm/year. Batia is also concerned about the effect of the free-price policy on agriculture and he proposes to analyze the alternatives which limit the decrease in the quantity of water supplied to agriculture in Batia to no more than 20 percent, relative to the present supply, and also alternatives without this constraint. The present supply in Batia, as well as the supply according to the agreed upon *Reference Alternative 2,* is determined by the fixed-price policy, which allocates about two-thirds of the total water supply in Batia to agriculture. Alfa would like to explore the alternatives with and without the connection between its two parts. All these considerations are formulated in the four regional alternatives given in Table 5.19:

Table 5.19: Regional alternatives considered in the second round of the negotiations

<table>
<tr><td rowspan="5">Common characteristics of the four regional alternatives:
Alfa:
Free-price policy;
Ensured minimum future demands; no subsidy on prices charged to agriculture
Batia:
Free-price policy;
Ensured minimum required quantities of water to consumers in Batia; supply from the Aquifer to the Central West District limited to 15 mcm/year.</td><td>Regional alternative</td><td>Water conveyance system between the two parts of Alfa</td><td>Decrease in quantity of water supplied to agriculture in Batia (relative to the present supply)</td></tr>
<tr><td>1</td><td>No</td><td>Not limited</td></tr>
<tr><td>2</td><td>Yes</td><td>Not limited</td></tr>
<tr><td>3</td><td>No</td><td>Limited to 20 percent</td></tr>
<tr><td>4</td><td>Yes</td><td>Limited to 20 percent</td></tr>
</table>

Results of the WAS runs for the four alternatives are given in Tables 5.III.9 and 5.III.10 in Appendix 5.III. Table 5.20 presents these regional alternatives as bundles of the allocated shares in the Aquifer and the net economic gain achieved by selecting each of them over Reference Alternative 2 (individual net economic gains are calculated by allocating half of the total net economic gains; in reality, the split of the total gains can be a subject to bargaining between the parties).

Table 5.20: Allocations and net economic gains achieved by the alternative negotiation solutions in the second round of negotiations

Alternative	ALFA		BATIA	
	Allocation of the disputed Aquifer mcm (%)	Net economic gain (m$) relative to Ref. Alt. 2	Allocation of the disputed Aquifer (mcm)	Net economic gain (m$) relative to Ref. Alt. 2
Reg. Alt. 1	132 (21%)	81	498 (79%)	81
Reg. Alt. 2	175 (28%)	95	455 (72%)	95
Reg. Alt. 3	170 (21%)	69	500 (79%)	69
Reg. Alt. 4	170 (27%)	80	461 (73%)	80
Reference Alt. 2	148 (23%)	0	484 (77%)	0

Suppose that Alfa decides to remove the objectives *Independent supply* and *Ownership* from the set of his negotiation objectives, as non-relevant: their importance relative to the other three objectives in the first round of negotiations was extremely low (Table 5.16), and he does not consider them more important in this round. He revises his preferences over the other three objectives and obtains the following utility function:

$$U^A(a_i) = 0.43w_i^{EC} + 0.43w_i^{AGR} + 0.14w_i^{REL} \qquad (5.5.4)$$

Next, suppose that Batia decides that the set of his negotiation objectives should include the same five objectives from the previous round (Equation 5.4.2), but he is not sure about their relative importance: once Batia enters water trade, it is better for her to have good relationships with Alfa. Also, the present potential negotiation resolution (*Reference Alternative 2*) does not improve the economic efficiency of already inefficient (economically) domestic water utilization. He revises his preferences and obtains the following utility function:

$$U^B(a_i) = 0.11w_i^{EC} + 0.16w_i^{IND} + 0.16w_i^{RELAY} + 0.30w_i^{SOC} + 0.27w_i^{RELAT} \qquad (5.5.5)$$

According to this function, *Relationship with Alfa* turns out to be almost twice as important as the rest of the objectives. Weights of the other four objectives have become much closer to one another.

Tables 5.21, 5.22, and 5.23 present the results of Alfa and Batia’s individual evaluations of the five alternatives and the Nash products of their final utility scores.

Table 5.21: Alfa's utility scores of the alternatives in the second round of the negotiations

Alternative	Utility values for the alternatives (ALFA)			Overall utility
	Economic Efficiency *0.43*	Intensification of agriculture *0.43*	Relationship with Batia *0.14*	
Reg. Alt. 1	0.58	1.00	1.00	**0.82**
Reg. Alt. 2	1.00	1.00	1.00	**1.00**
Reg. Alt. 3	0.33	1.00	1.00	**0.72**
Reg. Alt. 4	0.58	1.00	1.00	**0.82**
Reference Alt. 2	0.15	0.25	1.00	**0.22**

Table 5.22: Batia's utility scores of the alternatives in the second round of the negotiations

Alternative	Utility values for the alternatives (BATIA)					Overall utility
	Economic Efficiency *0.11*	Independent water supply *0.16*	Reliable water supply *0.16*	Social stability *0.30*	Relations with Alfa *0.27*	
Reg. Alt. 1	0.58	1.00	0.30	0.16	1.00	**0.58**
Reg. Alt. 2	1.00	1.00	0.30	0.16	1.00	**0.63**
Reg. Alt. 3	0.33	1.00	0.56	0.42	1.00	**0.68**
Reg. Alt. 4	0.58	1.00	0.56	0.42	1.00	**0.71**
Reference Alt. 2	0.15	1.00	1.00	1.00	0.33	**0.73**

Table 5.23: The Nash products of the utility scores of the alternatives in the second round of the negotiations

Alternative	Utility values		The Nash Product
	Alfa	**Batia**	
Reg. Alt. 1	**0.82**	**0.58**	**0.49**
Reg. Alt. 2	**1.00**	**0.63**	**0.63**
Reg. Alt. 3	**0.72**	**0.68**	**0.49**
Reg. Alt. 4	**0.82**	**0.71**	**0.58**
Reference Alt. 2	**0.22**	**0.73**	**0.16**

The results show that the *Reference Alternative 2* is still "the best" alternative according to Batia's preferences in this negotiation round, but it is "the worst" according to Alfa's preference system. Obviously, by moving from Reference Alternative 2 to any other alternative, Alfa gains more satisfaction, while Batia's satisfaction with the solutions decreases. However, differences in Batia's utilities among the five alternatives are not so significant (they range from 0.58 to 0.73), while Alfa's utilities range from 0.22 to 1. The Nash products indicate that the fairest alternative is the second one. Even though it seems "unfair" towards Batia to select this alternative as the (potential) final negotiation resolution (*Reference Alternative 3*), it is still the solution by which Alfa gains (much) more than Batia loses, relative to *Reference Alternative 2*. Net economic gain provided by this solution is equal to both parties (81 m$).

5.5.2.6 Stability of the solution (the third round of the negotiation process)

In the next stage of the negotiation process, the mediator and/or the parties explore the possibility to improve *Reference Alternative 3*. Up to this point of the negotiation process, the parties have moved, gradually, from clear dispute positions toward cooperation in terms of trade in water, and from there toward a regional solution in which criteria such as *Ownership over the Aquifer* and *Independency in water supply* have lost a great deal of their relative importance. According to Alfa's two most important objectives from the last negotiation round, a solution "better" than *Reference Alternative 3* could be the one which increases the economic gain and/or contributes to intensification of Alfa's agriculture. The fact that Alfa would approve of this solution would positively affect the relationship between the two parties – which is one of the two most important criteria in Batia's set (Equation 5.4.5). The mediator considers a scenario which would utilize the regional water sources in an economically more efficient way.

Since the concerns regarding *Independent water supply* are removed (by Alfa) or released (by Batia), the mediator suggests a dependency-based regional scenario, to challenge the stability of *Reference Alternative 3*. According to this scenario, a pipeline added to Batia's National Conveyance System would supply water to Alfa's Coastal Area. In order to balance such dependency of Alfa on Batia, Batia would be allowed unlimited quantities of water to be supplied from the disputed Aquifer to its Central West district. The rest of the important features of the scenario are the same as in the *Reference Alternative 2*: The disputed Aquifer is treated as a common pool; Alfa does not subsidize its agriculture, future demands in Alfa are satisfied and minimum quantities of water to urban and industrial consumers in Batia are assured.

According to the WAS optimized results, the added pipeline supplies an annual quantity of 38 mcm to Alfa's Coastal Area. This scenario provides more water to agricultural consumers in Batia, and a higher joint net economic benefit from water use, than *Reference Alternative 3*. The results of the WAS run are given in Tables 5.III.11 and 5.III.12.

Table 5.24: Allocations and net economic gains achieved by the alternative negotiation solutions in the second round of negotiations

Alternative	ALFA		BATIA	
	Allocation of the disputed Aquifer mcm (%)	Net economic gain (m$) relative to Ref. Alt. 3	Allocation of the disputed Aquifer (mcm)	Net economic gain (m$) relative to Ref. Alt.3
***Mutual dependency* Reg. Alt.**	127 (20%)	10	503 (80%)	10
Reference Alt. 3	175 (28%)	0	455 (72%)	0

The new proposed alternative allocates much less of the Aquifer to Alfa than *Reference Alternative 3* (from 28, the allocation decreased to only 20 percent). However, it still satisfies the future demand for all water uses in Alfa (additional water is imported from Batia by the new pipeline). Suppose that Alfa does not change the set and the weights of his negotiation objectives. Then, a possible outcome of Alfa's pair-wise comparison of the two alternatives might be as given in table 5.25.

Table 5.25: Alfa's utility scores of the alternatives in the third round of the negotiations

Alternative	**Utility values for the alternatives (ALFA)**			**Overall utility**
	Economic Efficiency *0.43*	Intensification of agriculture *0.43*	Relationship with Batia *0.14*	
***Mutual dependency* Regional alternative**	1.00	1.00	1.00	**1.00**
Reference Alt. 3	0.50	1.00	0.33	**0.69**

According to the same set and relative importance of the objectives Batia used in the second negotiation iteration, the new alternative is better than *Reference Alternative 3*: it has a better performance according to all Batia's objectives, except *Independency in water supply* (Table 5.26).

Table 5.26: Batia's utility scores of the alternatives in the third round of the negotiations

Alternative	**Utility values for the alternatives (BATIA)**					**Overall utility**
	Economic Efficiency *0.11*	Independent water supply *0.16*	Reliable water supply *0.16*	Social stability *0.30*	Relations with Alfa *0.26*	
***Mutual dependency* Reg. Alt.**	1.00	0.20	1.00	1.00	1.00	**0.87**
Reference Alt. 3	0.50	1.00	0.33	0.33	0.20	**0.42**

Table 5.27: The Nash products of the utility scores of the alternatives in the third round of the negotiations

Alternative	Utility values		The Nash Product
	Alfa	Batia	
Mutual dependency **Reg. Alt.**	**1.00**	**0.87**	**0.87**
Reference Alt. 3	**0.69**	**0.42**	**0.30**

It is obvious, that for the assumed preference systems, the new proposed alternative increases the level of satisfaction of both parties, and therefore, the Nash product as well (Table 5.27). Under the assumption that neither the parties nor the mediator have new ideas for the further improvement of the negotiation solution, this alternative is agreed to be the final negotiation outcome.

5.5.3 Comments on the exercise with simulated actors

The exercise with simulated actors (ESA) shows in detail the stages of a hypothetical negotiation process, supported by the NSS. Except for the initial "independent subjective input" regarding the ranks of the parties' negotiation objectives (provided by two particular candidates from the exercise with real actors (ERA), all other subjective considerations of the negotiators as of individual decision makers, are performed by the researcher. Our argument is that the way the "negotiations" were "conducted" in this exercise is only one of many, yet indicates how a real negotiation process might proceed, given the same initial conditions (the same "independent subjective input"). Furthermore, the conclusions drawn from this exercise are not affected by the specific "subjective considerations" and "subjective preference systems" of the researcher, nor by the direction the simulated negotiation process took.

The basic advantage of the exercise with simulated actors over the exercises with human actors is in the case study which can be complex enough to show (emphasize) the potential of the components of the NSS (simulations with real actors, at least in hour case, could have not been performed on such complex case study).

5.5 Summary

In this Chapter, the results of the empirical evaluation of The Negotiation Support System were presented. The NSS was evaluated through a series of simulated negotiation exercises with real actors, and by an explanatory exercise in which the subjective judgments of the negotiation parties were simulated.

The experimental evaluation was aimed at testing the six basic propositions (given in 5.1) regarding the contribution of the NSS to the quality of interaction between the negotiating parties and the quality of the final negotiation outcome.

Because of the difficulties explained in 5.3.7, the proposition on *contribution of the NSS to creativity of the parties in searching for new alternative solutions* was difficult to test by exercises with real actors (ERA). However, the explanatory exercise (ESA) demonstrated how the components of the NSS could be used to enlarge the set of considered alternatives: a party can use the WAS model to project a simple bargaining proposition (for example a 40-60 percent allocation of the disputed resource) into a number of alternatives for consideration within his individual consequence space. He can also range these alternatives according to their “goodness”, by analyzing his system of preferences by the individual decision support tool (the AHP model). This way, from a single alternative, which can be either “acceptable” or “unacceptable”, a party can create a set of differently valued alternatives.

Also, the NSS provides the assistance to the parties in creating new propositions, both individually and jointly. By breaking the water allocation problem into a number of individual negotiation objectives, and by knowing the relative importance of each objective, a party has a basis to analyze (again, by WAS) and propose alternative solutions which contribute to his most important objectives. We believe that the most beneficial way to use the NSS, is negotiation “around” the WAS model in which, the parties actually bargain over various details of regional water allocation scenarios. This way, the negotiation over one issue - allocation of the disputed water resource, becomes the negotiation over a set of issues which constitute a *regional water allocation scenario.*

Only simulations with real actors are appropriate for testing the effect of the NSS on the extent to which the parties *exchange information* and *negotiate in a cooperative manner*. However, in ERA we conducted, the participants were trained mediators, already inclined to search for solutions which benefit all involved parties. According to their subjective opinion, they all, without any difference between those who used the NSS and those who did not, freely shared information and negotiated in a cooperative manner. We believe that in simulations conducted even with the same participants, but in more appropriate conditions (longer duration, proper training of the participants to use the NSS), the effect of the NSS on the level of cooperation and information exchange would be more obvious.

Examples of opportunities for cooperation were demonstrated in the explanatory exercise (ESA).

Contribution of the NSS to the parties' *clarity regarding their individual preference systems* is shown in simulations with mediators. The participants who negotiated with the NSS had a clear picture regarding the set, as well as the relative importance of their negotiation objectives, while those who negotiated without the NSS, did not have.

Dynamic changes in individual preference systems were not proven in simulations with real actors. We believe the reason for that is first, the lack of time, and second, the fact that the NSS used in the simulations did not include the protocol of interaction, which prescribes an *iterative manner of negotiation*. In the explanatory exercise (ESA), the iterative manner of negotiation was applied and a possible scenario of dynamic changes in individual preference systems was demonstrated.

Contribution of the NSS to the economic efficiency of the negotiation outcome was observed in simulations with mediators: in each of the three pairs who negotiated with the WAS model, while in only one pair of those who negotiated without it, both parties improved their individual net economic benefit by the final negotiation outcome. However, since the total number of pairs is too small (only six), the ERA simulations cannot provide a basis for the analysis of these differences in terms of statistical significance. The explanatory exercise (ESA), shows the way the NSS can assist in searching for solutions which improve the economic efficiency, provided that at least one party considers the economic efficiency an important negotiation objective. Basis for the assumption that economic considerations can be important and represent an attractive way of enlarging the "cake", was elicited from the simulation with real actors: in both series of ERA simulations (with the students and the mediators), economic considerations were present in most individual sets of objectives and, in majority of cases, were included in the final negotiation outcome.

Chapter 6

Summary, conclusions and suggestions for further studies

6.1 Summary

The objective of this research has been to develop and test a Negotiation Support System (NSS) for aiding neighboring countries in negotiations over the disputed allocation of a shared water resource that is used to its full potential. The negotiation centers on allocating the scarce resource between the two parties, and takes into consideration all objectives of each party that are affected by the allocation. The NSS can, in fact, be used by two districts within one country, but the assumption is that there is no supreme authority above the negotiating parties that can impose upon them rules of conduct, let alone a specific solution to the allocation issue, and therefore they have to settle matters between them. Furthermore, there is an underlying assumption that the relations between the two countries are not cooperative, that communication between them is poor to begin with, and therefore the NSS should help in overcoming these difficulties and still strive to reach a mutually satisfactory solution to the allocation issue.

The main features of the negotiation process and the corresponding elements of the NSS developed in this study are:

1. Negotiation is modeled as an *iterative* process. Each iteration contains an evaluation of objectives and options that is conducted separately by each party,

and joint evaluation by both parties of solutions proposed for the allocation problem.

2. At each iteration, each party re-evaluates its own objectives (such as supply reliability, support of its agricultural sector, environmental concerns, relations with its neighbors, international reputation, etc.) and their relative importance. This is done in view of information, reference alternative and other negotiation conditions that have been generated during previous iterations (relationship, level of trust). The updated utility function is used in evaluating further alternative solutions. Creation of the utility function is performed with the Analytic Hierarchy Process (AHP, Saaty 1980); components and weights are allowed to change between iterations.
3. At each iteration, each party uses its "countrified" version of the Water Allocation System (WAS, Fisher et al. 2002 and 2005) to determine the optimal utilization of its allocation from the shared source and all its other sources, so as to maximize total net benefit within its territory. The optimization is run under a set of constraints that reflect hydrological, physical, legal, administrative, and any other conditions resulting from the negotiation process to this point. Maximum net economic benefit constitutes one (but only one) of the party's objectives.
4. At each iteration, the parties get together to *interact*, to create and examine jointly new proposed solutions, as mapped in the space of their joint utility functions. They seek to move towards joint improvement of their utilities, towards the current Pareto frontier (whose location is in fact not known), and move beyond it (thereby actually creating a new, again not known, Pareto frontier) by redefining and refining their utilities and constraints. This step uses the Nash approach to propose a best compromise solution, and is also designed to expand the domain of admissible solutions in utility space.
5. This evaluation can be aided by joint use of the WAS model, which is in that case run in a "regional" version, covering the territory of both parties.
6. While the allocation is modified from one iteration to the next, the party receiving more water can offer the other a "side payment", i.e., a financial compensation of some magnitude, which the parties can evaluate in view of the loss of net economic benefit that accrues to the party giving up some water and the economic gain to the other.

7. The entire negotiation process is governed by a "protocol of interaction" between the parties, that is designed to allow them discrete separate (private) evaluations and joint (public) ones.
8. The negotiation process ends when the parties cannot find (design) a solution better (at least from perspective of one of them) from the one selected as the best in the last iteration (breaking off the negotiations is one of the possible outcomes).

The NSS was evaluated in a series of simulated negotiation exercises with two groups of real actors (students and professional mediators), and by an explanatory exercise in which the subjective judgments of the negotiation parties were simulated. The results showed that economic considerations can represent an attractive means for "enlarging the pie" in negotiations over the allocation of water resources. The individual decision support provided by the AHP algorithm assisted the parties in structuring and weighing their preferences with respect to the negotiation problem. The WAS model and the other NSS components were shown to have the potential to improve the communication and information exchange between the parties, as well as their creativity in searching for alternative negotiation solutions.

6.2 Conclusions

Our NSS applies *efficiency*, *symmetry*, and *equity* as criteria for the negotiation process and for selection of “the best negotiated” alternative. It differs from other models (like CRSS of Rajasekaram, et al., 2002, Shared Vision Modeling of Palmer et al., 1993 and OASIS, HydroLogics, Inc.) in several aspects:

a. The NSS does not require mutual agreement on the issues to be negotiated: each party structures the overall water allocation problem in its own individual set of issues and goals, independently of the other party.
b. The NSS requires a detailed examination and specification of each party’s own individual objectives and preference structure.
c. The NSS prescribes an iterative manner of interaction, so that in each iteration the parties can evaluate their preference systems from a new and current perspective. In this way, the NSS provides the opportunity to the parties to gradually change their attitudes regarding the water allocation problem, and consider solutions that

they were unaware of or were not ready to consider at the beginning of the negotiations.

d. The NSS offers the parties a means for joint selection of a single ("the best") negotiation solution, from a set of alternatives (using the Nash solution).

6.3 Suggestions for further studies

A noted deficiency of this study is that the simulations were only partially successful. This was due to the logistic difficulty in getting participants to spend the length of time that would be required to comprehend fully the NSS and the use of its tools, and to conduct a sufficiently long sequence of iterations that would demonstrate its value in improving the negotiation *process* as well as the negotiation *outcome/solution.*

We expended much effort in extracting meaningful results from the simulation that we managed to conduct, and resorted to a self-driven set of simulations to complement what could be obtained from simulations with real actors.

Hence we suggest further simulated experiments, to build a body of results that provides more reliable conclusions regarding the validity and value of the NSS. This could possibly be done via the internet (ICONSnet, http://www/icns.umd.edu). The teams can be located in different countries and come from different backgrounds and belief systems. Internet communication will allow a lengthy (weeks, months) process of iterative communication, as prescribed by our NSS. It would provide a better data base for evaluating the NSS. Furthermore, experience gained in the simulations could lead to modifications in the NSS, to increase its efficacy as a support for negotiation of scarce resources.

Another possibility is to expand the perspective to include water quality, in addition to water quantity. The importance of water quality in international water relations is increasingly emerging as a critical issue, yet international water law is even vaguer about quality than about quantity (Shmueli and Shamir, 2001). The optimal allocation model would then have to be expanded to include water quality, in the sources and the supplies.

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APPENDIX 5.I: THE CASE STUDY FOR THE SIMULATION EXERCISE

משא ומתן בין אלפה ובטייה על ניצול מי האקוויפר המשותף

רקע כללי

הספקת מים בשתי מדינות שכנות, אלפה ובטייה, תלויה במקור מים משותף בין שתיהן – האקוויפר. לשתי המדינות היסטוריה ארוכה של איבה הדדית. בנוסף לאקוויפר, כל אחת משתי המדינות משתמשת במים ממקורות אחרים שלא נמצאים בסכסוך בינן. כל שנה הן מנצלות את היבול השנתי המקסימלי של המקורות האלה, ועדיין הביקוש האמיתי למים בשתיהן גדול מהכמות של המים הזמינים. שתיהן מעוניינות לקבל זכות להשתמש בחלק גדול ככל האפשר של האקוויפר.

בעת הנוכחית מצויות אלפה ובטייה בתהליך של משא ומתן על שיפור יחסים בינן, והטענות המנוגדות שלהן לגבי האקוויפר הן אחד מהנושאים החשובים ביותר בתהליך זה.

נתונים על שתי המדינות מצויים בטבלה המצורפת.

בטייה היא המדינה המפותחת יותר ביחס לאלפה, עם תל"ג גדול יותר, וצריכת מים לנפש גדולה מזו שבאלפה. השימוש הנוכחי במי האקוויפר הוא: מסך 680 מלמ"ק (מיליון מטר מעוקב) של היבול השנתי הממוצע של האקוויפר, בטייה משתמשת ב- 82 אחוז (560 מלמ"ק) ואלפה ב- 18 אחוז (120 מלמ"ק).

לשתי המדינות יש גישה לים ואפשרות להתפיל מים במחיר גבוה של 0.8 דולר לכל מטר מעוקב. בינתיים, אף אחת מהן לא מתפילה מי ים.

במזרח זורם נהר, ובטייה בנתה מובל כדי לספק מים לצרכנים (ישובים וחקלאות) במישור. מפני שהיחסים בין שתי המדינות מתוחים, מוביל זה מספק מים גם לעיר הראשית של בטייה, המסומנת B, בדרך ארוכה ויקרה, במקום שהמים יסופקו מהאקוויפר המשותף.

טענות לגבי מי האקוויפר

בהתאם ל- "זכות לפי כרונולוגיה", למדינה שהתחילה ראשונה להשתמש במים ממקור משותף יש זכות להמשיך להשתמש במקור זה על פי צרכיה בלי להתייחס לצרכי המדינה השכנה. במקרה של אלפה ובטייה, אין אפשרות להגדיר מי הייתה הראשונה שהשתמשה במי האקוויפר. עם זאת, בטייה הקימה תשתית לשימוש במים הרבה לפני אלפה. על סמך עובדה זו, בטייה טוענת שכדי לשמור על קצב הפיתוח של החקלאות והאוכלוסיה, היא צריכה לקבל זכות להמשיך ולהשתמש בלפחות 80 אחוז מן היבול השנתי של האקוויפר.

האקוויפר ממוקם תחת שטח של שתי המדינות, ומועשר במי גשמים היורדים על פני שטח גדול, ש- 80 אחוז ממנו שייך לאלפה. לכן, אלפה טוענת שבהתאם ל- "זכות לפי גיאוגרפיה", היא צריכה לקבל זכות לשימוש בכמות גדולה הרבה יותר מאשר 20 אחוז מן היבול השנתי הממוצע של האקוויפר.

הוראות למשתתפים במשא ומתן: פתרונות אפשריים

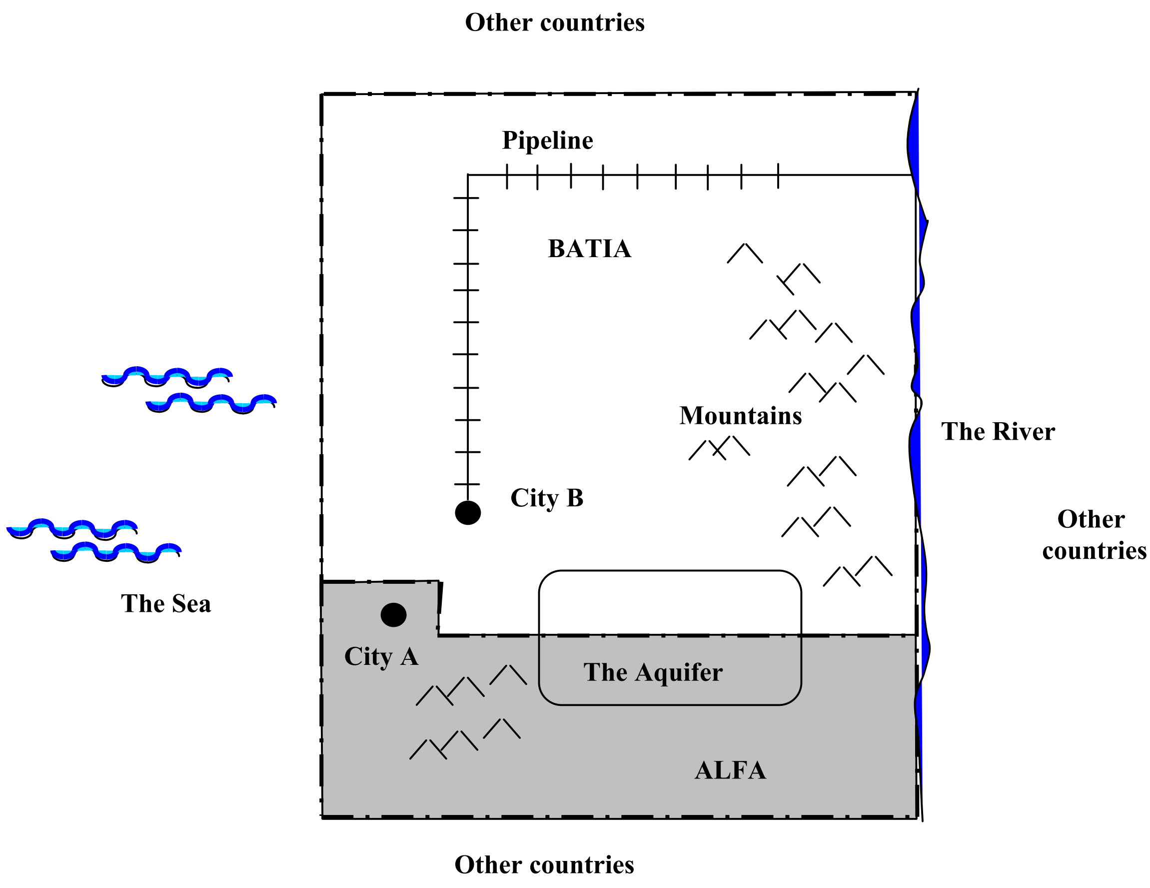
בתהליך משא ומתן מועלים לדיון פתרונות אפשריים לנושא הסכסוך. הפתרונות החלופיים במקרה שלפנינו יכולים לכלול את המרכיבים הבאים, חלקם או כולם, ומומלץ לשקול פתרונות יצירתיים נוספים:

1. חלוקה קבועה של מי האקוויפר (של היבול השנתי הממוצע שלו). זו הכרזה על זכויות המים של הצדדים: 680 מלמ"ק = $Q_A + Q_B$, כאשר Q_A ו- Q_B הן כמויות המים המוקצות לאלפה ובטייה, בהתאמה. מים השייכים למדינה אחת לא יהיו זמינים למדינה שנייה.
2. התפלת מי ים.
3. סחר במים, שפירושו כלהלן: לאחר שמוכרות זכויות המים של כל צד, כל מדינה רשאית למכור אותם לצד השני, במחיר שיוסכם בין הצדדים, או תמורת סחורות אחרות (למשל: תוצרת חקלאית).
4. הסכמה על הקמת פרוייקטי מים עתידיים, חד- או דו-צדדיים. למשל: בניית מתקנים להתפלת מים או בניית מערכת להעברת המים בתוך אחת המדינות או בין שתי המדינות.
5. סידורים מפורטים לגבי מימון של פרוייקטים בניהול משאבי מים. במקרה שלא ידוע לך מהי עלות של איזשהו פרוייקט, ניתן להציע את חלוקת העלות בין הצדדים (למשל, 50% - 50%).

נתונים על שתי המדינות

	אלפה	בטייה
שטח (קמ"ר)	6000	20000
שטח מושקה (קמ"ר)	150	2000
עובי גשם שנתי (מ"מ)	500	600
אוכלוסייה נוכחית	2,000,000	5,000,000
תל"ג (מיליון דולר לשנה)	2,000	75,000
תל"ג לנפש (דולר לנפש לשנה)	1,000	15,000
זמינות מים נוכחית (מלמ"ק) מהאקוויפר: ממקורות אחרים (הנהר ומקורות אחרים שאינם נושא בסכסוך): סה"כ:	 120 90 210	 560 1140 1700
צריכת מים נוכחית (מלמ"ק לשנה) אוכלוסיה: חקלאות: סה"כ: **צריכה לנפש (מ"ק\נפש\שנה):** אוכלוסיה: חקלאות:	 90 120 210 45 60	 600 1100 1700 120 220
ביקוש עתידי למים (מלמ"ק לשנה) אוכלוסיה: חקלאות: סה"כ: **ביקוש עתידי לנפש (מ"ק\נפש\שנה):** אוכלוסיה: חקלאות:	 120 140 260 60 70	 650 1250 1900 130 250
עלות שאיבה מהאקוויפר $(\$\backslash m^3)$:	0.25	0.08
עלות של הספקת מים ממקורות אחרים $(\$\backslash m^3)$: לאזור העירוני: לאזור החקלאי:	 0.02 -	 0.4 0.2
עלות של התפלת מי ים $(\$\backslash m^3)$: (רק לאזורים עירוניים בשתי המדינות יש גישה לים)	0.8	0.8
עלות העברת מים בתוך המדינה $(\$\backslash m^3)$:	0.4	0.2
עלות העברת מים בין שתי המדינות $(\$\backslash m^3)$:	0.2	

Figure 1. The Map of the Region



הוראות סודיות לנציגי אלפה

השנה היא 2001. מונית על ידי הנשיא לייצג את אלפה במשא ומתן על הקצאת זכויות לשימוש במי האקוויפר בעתיד.

משימתך להבטיח את הגדלת כמות המים למדינה שלך. צריכת המים באלפה כיום היא בערך 230 מלמ״ק. צריכה המים לנפש נמוכה. אתה משוכנע שהסיבה לכך היא, לפחות חלקית, החלוקה הנוכחית של מי האקוויפר.

במשך המשא ומתן את/ה אמור לחשוב על המטרות הבאות:

1. התחייבת אישית לנשיא להשיג עיסקה שתבטיח לאלפה זכות לשימוש בחלק גדול יותר של מי אקוויפר. יהיה לך קשה לחזור הביתה עם הסכם לא טוב. הסכם טוב יהיה גם לטובת הקריירה האישית שלך.

2. למדינה שלך יש כרגע זכות להשתמש ב- 18 אחוז של מי האקוויפר (120 מלמ״ק) בעוד ש- 80 אחוז מן השטח שממנו מקבל האקוויפר מי גשם שייך לאלפה. למרות שלא קיים חוק בין לאומי שמקשר בהכרח בין שטח כזה להקצבת זכויות לשימוש במים, אתה משוכנע שהכלל המקובל ברבים – הקצבה בהתאם לזכות לפי גיאוגרפיה – תופס במקרה של האקוויפר, ולטובת המדינה שלך.

3. הביקוש העתידי באלפה הוא בערך 260 מלמ״ק , מפני שבשני המגזרים העיקריים (עיר וחקלאות) צפויה עליה ניכרת של הביקוש ביחס למצב הנוכחי (ראה בטבלה). האזור העירוני, הממוקם במישור החוף, זקוק תוספת מים, היכולה להתקבל מ: א. התפלת מי ים במחיר של 0.8 דולר\מ״ק, ב. בניית מוביל מן האקוויפר שיספק מים במחיר של 0.65 דולר\מ״ק (0.25 דולר\מ״ק עולה השאיבה מהאקוויפר ועוד 0.4 דולר\מ״ק להובלה).

4. המדינה שלך לא מפותחת ועשירה כמו בטייה. אין לה יכולת כלכלית לפתח תעשייה. הדרך האפשרית להגדלת התל״ג היא הגברת הייצור החקלאי, ואולם עם הכמות הנוכחית של המים הדבר בלתי אפשרי. התפלת מי ים היא פתרון יקר, מפני שעלות העברת מים ממתקן התפלה בחוף לאזור החקלאי גבוהה מאוד (ראה את הטבלה: 0.8 + 0.4 = 1.2 דולר\מ״ק).

5. העדיפות העליונה שלך היא להגדיל את החלק של מי האקוויפר השייכים למדינה שלך. הסכם שלא יבטיח לאלפה לפחות 60% של מי האקוויפר יחשב הסכם לא טוב.

6. אלפה ובטייה נמצאות במשא ומתן על שלום ביניהן, ובתהליך זה נושא המים חשוב מאוד. המדינה שלך הייתה רוצה לשים קץ לסכסוכים, אך יהיה קשה להתקדם במשא ומתן הכללי אם לא יהיה הסכם ביחס לאקוויפר. אף על פי כן, עדיף לא להגיע להסכם מאשר להגיע להסכם לא טוב.

7. הסכסוך בין אלפה ובטייה נמצא במרכז תשומת הלב של הקהילה הבינלאומית, המצפה שתהליך השלום יסתיים בהצלחה. יהיה טוב למעמד הבינלאומי של אלפה אם יהיה הסכם עם בטייה.

8. מותר לך לשקול פתרונות המבוססים על שיתוף פעולה (בניה משותפת של תשתית, מימון וכו׳). את/ה נחשב/ת בעל/ת ידע וניסיון מתאימים כדי לקבל החלטות כאלה (הנתונים בטבלה יכולים לעזור לך). את/ה יודע/ת שהציבור במדינה שלך חלוק בדיעותיו באשר לשיתוף פעולה עם בטייה. חלק מסוים של הציבור יתמוך בפתרונות כאלה, אך חלק אחר יתנגד. אם ההסכם יהיה מבוסס על שיתוף פעולה יהיה צורך להסביר אותו לפוליטיקאים ולעם.

להלן רשימת המטרות שלך במשא ומתן (הרשימה לא בהכרח מלאה ולא בהכרח לפי סדר עדיפות):

1. **להגיע להסכם.**
2. **לא לסכן את הקריירה שלך.**
3. **להגדיל את כמות המים הזמינים למדינה שלך.**
4. **להבטיח הספקת מים שתהיה יעילה כלכלית .**
5. **לשפר את התנאים למגזר חקלאי במדינה שלך.**
6. **לשפר יחסים עם בטייה.**
7. **לשמור על המעמד הבינלאומי של המדינה שלך.**

את סדר העדיפות או המשקל היחסי של המטרות עליך לקבוע בעצמך.

איך להשתמש בנתונים ובמטרות שלך, והאם בכלל לגלות אותם תוך כדי תהליך המשא ומתן – תלוי בך אישית.

המידע הזה יכול לעזור לך לבנות את הבסיס לטענות ולעמדה שלך במשא ומתן, אבל הוא עלול לעזור גם לנציג של בטייה להשיג את מטרותיו. לכן, ראוי להיזהר בבחירת האסטרטגיה שלך לניהול המשא ומתן.

הוראות סודיות לנציגי בטייה

השנה היא 2001. מונית על ידי הנשיא לייצג את בטייה במשא ומתן על הקצאת זכויות לשימוש במי האקוויפר בעתיד.

המשימה היא להשיג חלק גדול ככל האפשר של מי האקוויפר, בכדי לשמור על קצב ההתפתחות הנוכחי של האוכלוסיה, התעשייה והחקלאות במדינה. במשא ומתן יש להתחשב בשיקולים הבאים:

1. התחייבת אישית לנשיא להשיג עיסקה טובה. יהיה לך קשה לחזור הביתה עם הסכם לא טוב. הסכם טוב יהיה גם לטובת הקריירה האישית שלך.

2. צריכת המים הנוכחית בבטייה היא 1700 מלמ"ק, כולל 560 מלמ"ק מן האקוויפר. הביקוש השנתי בעתיד מוערך ב- 1900 מלמ"ק. כדי להבטיח הספקה אמינה, ממשלת בטייה שוקלת להתפיל מי ים, למרות שזה פתרון יקר מאוד (נתונים בטבלה). וויתור על חלק מן הזכויות הנוכחיות של בטייה במי האקוויפר, יגדיל עוד יותר את הצורך בהתפלה. מצפים ממך להשיג הסכם שיבטיח הקטנת הצורך להתפיל.

3. בערך שני שליש מן המים בבטייה משמשים לחקלאות, אך יש אפשרות לשקול הקטנת הכמות הזאת. ניתן לשקול הקטנת הייצור החקלאי תמורת יבוא של מוצרים חקלאיים. אבל הקטנת כמות המים לחקלאות עלולה לגרום לבעיות בבטייה, משתי סיבות:

א. בגלל היחסים המתוחים עם אלפה, וסיכון קבוע למלחמה, חשוב מאוד למדינה שלך להיות בלתי-תלויה בייצור מזון. הישובים החקלאים הממוקמים בגבולות של המדינה, חשובים גם מסיבות ביטחוניות.
ב. כל צמצום בייצור חקלאי יגרום לאבטלה והתמרמרות של החקלאים. למגזר חקלאי יש עוצמה פוליטית גדולה, וכל שינוי במגזר זה משפיע על הזירה הפוליטית במדינה. במקרה של צמצום בפעילות החקלאית, יהיה צורך להשקיע בתעשייה ובהכשרת כח האדם, על מנת להעסיק את החקלאים המובטלים.

4. למרות השאיפה להגיע להסכם, עדיף לא לקבל הסכם שיתן לבטייה פחות מ- 60 אחוז ממי האקוויפר.

5. מסיבות ביטחוניות, האקוויפר לא מתאים להספקת מים לעיר B, המקבלת מים מן הנהר (ראה את המפה) בדרך ארוכה ויקרה. הספקת מים לעיר B מהאקוויפר היה יתרון גדול לבטייה, אךלשם כך יש צורך להגיע למידה גדולה של אימון באלפה (בגלל הגישה הישירה שלה לאקוויפר), שלא תסכן את אספקת המים לעיר. רק הסכם שיהיה לשביעות רצונה של אלפה יאפשר אמון ברמה כזו בין שתי המדינות.

6. אלפה ובטייה נמצאות במשא ומתן על שלום ביניהן, ובתהליך זה נושא האקוויפר חשוב מאוד. מסיבות רבות, העדיפות הראשונה של המדינה שלך היא לסיים את הסכסוך עם אלפה. יהיה בלתי אפשרי להתקדם במשא ומתן הכולל על שלום אם לא יהיה הסכם ביחס לאקוויפר.

7. הסכסוך בין אלפה ובטייה נמצא במוקד תשומת הלב של הקהילה הבינלאומית, והיא מצפה שתהליך השלום יסתיים בהצלחה. לטובת מעמדה הבינלאומי של בטייה, יש להשקיע את כל המאמצים להשגת הסכם, אבל כבודה של בטייה יינזק אם תוותר על "יותר מדי" מהזכויות במי האקוויפר.

8. מותר לך לשקול פתרונות המבוססים על שיתוף פעולה (בניה משותפת של תשתית, מימון וכו'). את/ה נחשב/ת בעל/ת ידע וניסיון מתאימים כדי לקבל החלטות כאלה (הנתונים בטבלה יכולים לעזור לך). את/ה יודע/ת שהציבור במדינה שלך חלוק בדעותיו באשר לשיתוף פעולה עם אלפה. חלק מסוים של הציבור יתמוך בפתרונות כאלה, אך חלק אחר יתנגד. אם ההסכם יהיה מבוסס על שיתוף פעולה יהיה צורך להסביר אותו לפוליטיקאים ולעם.

להלן רשימת המטרות שלך במשא ומתן (הרשימה לא בהכרח מלאה ולא בהכרח לפי סדר עדיפות):

1. **להגיע להסכם.**
2. **לא לסכן את הקריירה שלך.**
3. **להבטיח הספקה אמינה של מים למדינה שלך.**
4. **להבטיח הספקת מים שתהיה יעילה כלכלית .**
5. **לשפר את היחסים עם אלפה.**
6. **להגיע להסכם שיבטיח רמה גבוהה של ביטחון למדינה.**
7. **להימנע מהסכם שיגרום לבעיות פוליטיות וחברתיות בבטייה.**
8. **לשמור על המעמד הבינלאומי של מדינה שלך.**

את סדר העדיפות או המשקל היחסי של המטרות עליך לקבוע בעצמך.

איך להשתמש בנתונים ובמטרות שלך, והאם בכלל לגלות אותם תוך כדי תהליך המשא ומתן – תלוי בך אישית.

המידע הזה יכול לעזור לך לבנות את הבסיס לטענות ולעמדה שלך במשא ומתן, אבל הוא עלול לעזור גם לנציג של אלפה להשיג את מטרותיו. לכן, ראוי להיזהר בבחירת האסטרטגיה שלך לניהול המשא ומתן.

APPENDIX 5.II: POST-SIMULATION QUESTIONNAIRE

כל משתתף מתבקש למלא את השאלון הבא: לסמן X במשבצת המתאימה.

1. עמדת הפתיחה שלך התבססה בעיקרה על המידע הכלכלי (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

2. כבר מתחילת התהליך הסתמכת על המידה הכלכלי בניתוח החלופות (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

3. השתמשת בנימוק הכלכלי לפתח את עמדותיך לכל אורך התהליך (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

4. מידע כלכלי היה חשוב ביותר בהצבת עמדותיך (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

5. המידע הכלכלי היווה בסיס לשיתוף פעולה בין הצדדים (EC, COOP).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

6. המידע הכלכלי סייע ליצירת חלופות חדשות (CREAT , EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

7. המידע הכלכלי סייע ליצירת חלופות שיתופיות (CREAT , COOP , EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

8. נושאים אחרים היו חשובים יותר מן הנושא הכלכלי (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

9. חשיבות המידע הכלכלי גדלה במהלך המו"מ (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

10. חשיבות המידע הכלכלי פחתה במהלך המו"מ (EC).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

11. היתה לך תפיסה ברורה באשר לקריטריונים לקבלת ודחיית חלופות (ORDER).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

12. יכולת להגדיר בבירור את מידת ההעדפה של חלופות אחת על אחרת (ORDER).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

13. דנת באופן חופשי עם הצד השני על הקריטריונים וההעדפות שלך, ולכן היתה השפעה ניכרת על תוצאות המו"מ (INFO).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

14. יכולת להעריך/לחשב כמה חשוב קריטריון אחד מאחר (ORDER).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

15. מרחב החלופות התרחב במהלך המו"מ (CHANGE).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

16. מערך הקריטריונים שלך השתנה במהלך המו"מ (CHANGE).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

17. המשקלות של הקריטריונים השתנו במהלך המו"מ (CHANGE).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

18. מידת שיתוף הפעולה היתה גבוהה (COOP).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

19. מידת היצירתיות (ביצירת חלופות) היתה גבוהה (CREAT).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

20. מידת חילופי המידע היתה גבוהה (INFO).

מסכים/ה מאד	מסכים/ה	נייטרלי	לא מסכים/ה	מאד לא מסכים/ה

APPENDIX 5.III:
DATA AND THE RESULTS OF THE WAS RUNS FOR THE EXERCISE WITH SIMULATED ACTORS

Available sources of water in the region with average annual replenishments:

1. The Northern Source (650 mcm);
2. The Coastal Aquifer (370 mcm);
3. The Aquifer (disputed, 630 mcm)
4. The Southern Source (55 mcm).

Table 5.III.1:Physically feasible water production within the districts, from the available sources

Districts		**Sources of water**
Batia	North	The Northern Source
	Center West	The Coastal Aquifer, The Aquifer (disputed)
	Center East	The Aquifer (disputed)
	South	The Southern Source
Alfa	The Coastal District	The Coastal Aquifer
	WB - West	The Aquifer (disputed)
	WB - East	The Aquifer (disputed)

Table 5.III.2: Current water consumption in Alfa

Districts in Alfa	**Water demand sector (water consumption in mcm/year)**			**Total**
	Urban sector	Industry	Agriculture	
The Coastal District	38	3	70	**111**
WB West	20	1	18	**39**
WB East	16	1	52	**69**
Total	**74**	**5**	**140**	**220**

Table 5.III.3: Future demand for water in Alfa

Districts in Batia	Water demand sector (demand in mcm/year)			**Total**
	Urban sector	Industry	Agriculture	
North	38	3	88	**129**
Center - West	20	1	23	**44**
Center - East	16	1	65	**82**
Total	**74**	**5**	**176**	**255**

Table 5.III.4: Current water consumption in Batia

Districts in Batia	Water demand sector (demand in mcm/year)			**Total**
	Urban sector	Industry	Agriculture	
North	90	18	507	**615**
Central West	290	60	384	**734**
Central East	115	24	219	**358**
South	42	6	143	**191**
Total	**537**	**108**	**1253**	**1898**

Table 5.III.5: Minimum required supply of water in Batia

Districts in Batia	Water demand sector (supply in mcm/year)			**Total**
	Urban sector	Industry	Agriculture	
North	90	18	240	**348**
Central West	290	60	190	**540**
Central East	115	24	100	**239**
South	42	6	70	**118**
Total	**537**	**108**	**600**	**1245**

Table 5.III.6 Alfa – Domestic Scenarios

Domestic scenario (water policy)	**Conveyance between the Coastal and WBW districts**	**Results (WAS)[1]**					
		Scen.	**Qtot mcm**	**Qdes mcm**	**Qagr mcm**	**Vtot m$**	**Qexcs mcm**
'40-60' (20 percent of the Aquifer for Alfa)							
Prices fixed at (0.65, 0.65, 0.15)[2]	No connection	1	219	21	140	175	123
	With connection	2	219	0	140	193	123
Free price policy	No connection	3	215	0	122	194	127
	With connection	4	243	0	146	197	99
Agriculture subsidized by 0.03 $/mc (free-price policy)	No connection	5	237	0	145	198	105
	With connection	6	273	0	176	201	69
Future deamand satisfied	No connection	7g	274	39	184	161	106
	With connection	8	281	0	184	195	60
'20-80' (20 percent of the Aquifer for Alfa)							
Prices fixed at (0.65, 0.65, 0.15)[2]	No connection	1	219	21	140	175	17
	With connection	2	219	3	140	193	0
Free price policy	No connection	3	215	0	122	194	0
	With connection	4	216	0	123	196	0
Subsidy or *assuring future demands* are not relevant, since all the available resources are used, and the additional quantities of water could be provided only by the expensive desalination.							

[1] Qtot = total annual water supply; Qdes = quantity of desalinated seawater; Qagr = total annual supply to agriculture; Vtot = total annual net benefit from water use; Qexcs = quantity of the Aquifer's water, not used; mcm = million cubic meters; m$ = million dollar.

[2] "Fixed price" policy with prices charged to urban, industrial, and agricultural consumers fixed to 0.65, 0.65, and 0.15 $/m^3$, respectively.

Table 5.III.7 Batia - Domestic Scenarios

Domestic scenario (water policy)	Supply from the disputed Aquifer to the Center West	Results (WAS)[1]				
		Scen.	Qtot mcm	Qdes mcm	Qagr mcm	Vtot m$
'40-60' (60 percent of the Aquifer for Batia)						
Prices fixed at (1, 1, 0.17)[2]	Limited	1	1879	516	1234	1619
	Not limited	2	1879	516	1234	1619
Free price policy	Limited	3	1416	53	718	1904
	Not limited	4	1363	0	691	1939
Supply to each consumer equal to minimum demand	Limited	5	1245	0	600	1834
	Not limited	6	1245	0	600	1880
'20-80' (80 percent of the Aquifer for Batia)						
Prices fixed at (1, 1, 0.17)[2]	Limited	1	1879	391	1234	1737
	Not limited	2	1879	390	1234	1746
Free price policy	Limited	3	1542	53	800	1928
	Not limited	4	1489	0	783	2040
Supply to each consumer equal to minimum demand	Limited	5	1245	0	600	1834
	Not limited	6	1245	0	600	1948

[1] Qtot = total annual water supply; Qdes = quantity of desalinated seawater; Qagr = total annual supply to agriculture; Vtot = total annual net benefit from water use; mcm = million cubic meters; m$ = million dollar.

[2] "Fixed price" policy with prices charged to urban, industrial, and agricultural consumers fixed to 1, 1, and 0.17 $/m^3$, respectively.

Table 5.III.8 Batia – trade in water

Domestic scenario (water policy)	Quantity of water earned by trade (mcm)	Supply from the disputed Aquifer to the Center West	Results (WAS)[1]				
			Scen.	Qtot mcm	Qdes mcm	Qagr mcm	Vtot m$
'40-60' (60 percent of the Aquifer for Batia) with water trade							
Prices fixed at (1, 1, 0.17)[2]	**60**	Limited	1	1879	447	1234	1694
		Not limited	2	1879	447	1234	1694
	127	Limited	3	1879	389	1234	1745
		Not limited	4	1879	391	1234	1737
Free price policy	**60**	Limited	1	1485	53	763	1921
		Not limited	2	1432	0	740	1997
	127	Limited	3	1543	53	813	1928
		Not limited	4	1490	0	796	2041
Supply to each consumer equal to minimum demand	**60**	Limited	5	1245	0	600	1834
		Not limited	6	1245	0	600	1918
	127	Limited	5	1245	0	600	1834
		Not limited	6	1245	0	600	1948

[1] Qtot = total annual water supply; Qdes = quantity of desalinated seawater; Qagr = total annual supply to agriculture; Vtot = total annual net benefit from water use (does not include the payment as the result of the trade in water; mcm = million cubic meters; m$ = million dollar.

[2] "Fixed price" policy with prices charged to urban, industrial, and agricultural consumers fixed to 1, 1, and 0.17 $/m^3$, respectively.

Table 5.III.9 Alfa – regional alternatives

Regional alternative	Results (WAS)[1]			
	Qtot mcm	Qdes mcm	Qagr Mcm	Vtot m$
1	262	39	176	162
2	264	0	176	195
3	258	39	176	161
4	259	0	176	194

[1] Qtot = total annual water supply; Qdes = quantity of desalinated seawater; Qagr = total annual supply to agriculture; Vtot = total annual net benefit from water use (does not include the payment as the result of the trade in water; mcm = million cubic meters; m$ = million dollar.

Table 5.III.10 Batia – regional alternatives

Regional alternative	Results (WAS)[1]			
	Qtot mcm	Qdes mcm	Qagr Mcm	Vtot m$
1	1535	53	797	1927
2	1494	53	768	1922
3	1695	210	987	1904
4	1688	242	988	1893

[1] Qtot = total annual water supply; Qdes = quantity of desalinated seawater; Qagr = total annual supply to agriculture; Vtot = total annual net benefit from water use (does not include the payment as the result of the trade in water; mcm = million cubic meters; m$ = million dollar.

Table 5.III.11 Alfa – 'Mutual dependency' alternative

Regional alternative	Results (WAS)			
	Qtot mcm	Qdes mcm	Qagr Mcm	Vtot m$
Mutual dependency	255	0	176	194

Table 5.III.12 Batia – 'Mutual dependency' alternative

Regional alternative	Results (WAS)			
	Qtot mcm	Qdes mcm	Qagr Mcm	Vtot m$
Mutual dependency	1583	133	925	1944

לענות על השאלון באמצעות סולם "ליקרט" בעל חמש רמות (five-point Likert scale). ניתוח התשובות נעשה על ידי כלים סטטיסטיים מתאימים לסוג זה של שאלונים:

א. אינדקס Alpha Cronbach ששימש כמדד לתקפות של הקבצת מספר שאלות לנתון משותף המתייחס למאפיין מסוים של משא ומתן;

ב. מודל רגרסיה (Nested Hierarchical Model) שהותאם לערכים הממוצעים של התשובות בכל מערך, כדי לבחון האם קיים הבדל מובהק בין התשובות של המשתתפים בשתי הקבוצות (עם ובלי ה-NSS).

הסימולציות עם השחקנים האמיתיים היו מוגבלות על ידי משך הזמן הקצר יחסית שיכלו להקדיש ל"משחק", וגם על ידי המיומנות המוגבלת של המשתתפים לעבוד עם תוכנות ממוחשבות. כתוצאה, היה ניתן לנתח ולבחון רק חלק ממאפייני ה-NSS.

הסוג השני של ניסויים בוצעו על ידי, כאשר עדיפויות סובייקטיביות התחלתיות של הצדדים במשא ומתן נלקחו מזוג משתתפים של הניסויים הקודמים. שאר השיקולים הסובייקטיביים הנדרשים במהלך האיטרציות של המשא ומתן ניתנו על ידי. מטרתו של תרגיל זה הייתה לבחון ולחקור, באופן מפורט, את היכולות של מודל WAS בתוך מסגרת של NSS, שאותן לא הצלחנו לבחון בסימולציות עם השחקנים האמיתיים.

המסקנות של ההערכה הניסויית של NSS הן, ראשית, שהשיקולים הכלכליים יכולים לשמש אמצעי ל"הגדלת העוגה" במיקוח על הקצאת מקורות מים משותפים. מסקנה נוספת היא, שהבנה טובה של מערכת עדיפויות אינדיבידואלית הינה תנאי הכרחי למציאת פיתרון שיהיה מקובל ולשביעות רצונם של שני הצדדים. הסימולציות עם שחקנים אמיתיים הראו שאלגוריתם AHP, כאשר הוא כלול במסגרתה-NSS, סייע לצדדים לבנות ולהבין את מערכת עדיפויות שלהם, וזה סייע להם להגיע להסכם. התוצאות גם הראו שלמודל WAS ולמרכיבים האחרים של NSS יש פוטנציאל לשפר את התקשורת והחלפת המידע בין הצדדים, וגם את היצירתיות שלהם בבניית פיתרונות חלופיים.

ה-NSS מסייעת לצדדים במשא ומתן להתקדם במרחב התועלת המשותף לכיוון פיתרונות יעילים, במונחים של שביעות הרצון (פונקציות תועלת) של שניהם. אחת מההנחות של עבודה זו היא שמערכת עדיפויות אינדיבידואלית קשורה למשא ומתן היא פונקציה של התנאים ברגע הנוכחי, כולל המידע הזמין באותה עת, התפתחות היחסים בין הצדדים במהלך המו״מ, והתועלת של מצב ללא הסכם (BATNA= הפיתרון הטוב ביותר כחלופה להסכם). כאשר תנאים אלה משתנים, המרכיבים של מערכת העדיפויות האינדיבידואלית יכולים להשתנות, וגם החשיבות היחסית שלהם. כתוצאה, כל שינוי בתנאים של המשא ומתן גורם לשינוי בפונקצית התועלת האינדיבידואלית. שלב של משא ומתן שבו תנאים אלה (ולכן גם פונקציית התועלת) קבועים, נקרא *איטרציה*. בכל איטרציה, מתבצעים תהליכים של יצירת הפיתרונות החלופיים וניתוחם, קביעת פונקציות תועלת אינדיבידואליות ובחירת הפיתרון ״הטוב ביותר״ (על פי מודל Nash) לאותה עת, בהתחשב בעדיפויות (פונקציות תועלת) של שני הצדדים. באיטרציה הבאה, הצדדים יכולים לשנות את מערך הקריטריונים ו/או את חשיבותם היחסית, בהשוואה לפיתרון ייחוס (reference alternative), המובטח על ידי האיטרציה הקודמת. תהליך איטרטיבי זה מסתיים כאשר אף אחד מהצדדים (או מגשר) לא יכול להציע פיתרון שישפר את התועלת עבור אחד מהם לפחות.

<u>בחינה ניסיונית של ה-NSS</u>

מטרתה של ההערכה הניסיונית הייתה לבחון את ההנחות הבסיסיות של המחקר לגבי תרומתה של ה-NSS לאיכות התהליך ולתוצאה של משא ומתן על מקורות מים בין-לאומיים. לפי ההנחות אלו התרומה הינה: יצירתיות של הצדדים בבניית פיתרונות חלופיים, שיפור בהחלפת מידע, שיפור בשיתוף הפעולה, הבנה טובה יותר של מערכת העדיפויות האינדיבידואלית, יעילות כלכלית של ההסכם, ורמת שביעות הרצון של הצדדים מן התוצאה הסופית של משא ומתן.

ה-NSS נבדקה בשני סוגים של ניסויים. הסוג הראשון היו <u>תרגילי סימולציה עם שחקנים אמיתיים,</u> ששיחקו משחק משא ומתן מבוסס על מקרה דמיוני של שתי מדינות שכנות הדנות על הקצאה ממקור מים משותף. זוגות המשתתפים חולקו לשתי קבוצות: בקבוצה אחת התנהל משא ומתן עם שימוש ב-NSS ובקבוצה השנייה ללא ה-NSS. ההנחות הנ״ל נבדקו על ידי השוואת התוצאות של שתי הקבוצות. המדדים הבאים שימשו לצורך ההשוואה:

1. תשובות של כל אחד מהמשתתפים לשאלות לגבי תהליך משא ומתן שבו השתתפו. (Post-simulation questionnaire). כל אחת מהשאלות התייחסה לפחות לאחד ממאפייני משא ומתן.
2. התועלת האינדיבידואלית והערך הכלכלי של התוצאה הסופית, וגם של כל הפיתרונות החלופיים שעליהם דנו הצדדים.

עבור הזוגות שניהלו משא ומתן ללא NSS, תועלות אינדיבידואליות וערכים כלכליים של פיתרונות חושבו אחרי סימולצית המשא ומתן, על ידי אלגוריתם AHP ומודל WAS. המשתתפים התבקשו

פיתרונות חלופיים

בזירה המשותפת (בה המידע גלוי), הצדדים דנים על הקצאתם של שני "משאבים": מים וערך כלכלי. מנקודת מבט של צד i פיתרון חלופי a מיוצג על ידי כמות המים מהמקור המשותף $Q_i(a)$ (מלמ"ק) וערך $v_i(a)$ (במונחים מוניטריים). $v_i(a)$ הוא הרווח הכלכלי נטו לצד i, כתוצאה מבחירת פיתרון חלופי a על פני איזושהי חלופת ייחוס, a_r (reference alternative). ערך זה מחושב כ-

$$, \ v_i(a) = V_i(a) - V_i(a_r) \pm v_{AB}$$

כאשר $V_i(a)$ ו-$V_i(a_r)$ הם הרווחים הכלכלים משימוש במים לפי חלופות a ו-a_r בהתאמה, ו-v_{AB} הוא "פיצוי" (side payment). צד אחד יכול להציע לשני פיצוי כספי כזה כדי להגדיל את האטרקטיביות של הפיתרון הנדון.

בזירה הפרטית של כל צד (בה המידע פרטי וחסוי), הוא מנתח את יעילות הפיתרונות החלופיים, שנוסחו בזירה הציבורית כ"זוג" $(Q_i(a), v_i(a))$ ביחס לכל אחד מהקריטריונים שלו. יהא $u_i^j(a)$ ($i = A,B \ \ j = 1,...,n$) המדד הסוביקטיבי, המתאר עד כמה חלופה a מספקת קריטריון j של צד i, אזי חלופה a מתוארת בזירה הפרטית על ידי וקטור $[u_i^1(a),...,u_i^n(a)]$, כאשר n הוא מספר הקריטריונים של צד זה. היעילות הכוללת של חלופה a, ביחס לכל הקריטריונים ביחד, מוגדרת על ידי פונקציית תועלת. עבור n קריטריונים של צד i, פונקציית התועלת היא

$$, \quad U_i(a) = w_i^1 u_i^1(a) + ... + w_i^n u_i^n(a), \ \ \sum_{j=1}^{n} w_i^j = 1$$

כאשר w_i^j הוא משקל של קריטריון j של צד i. כל המרכיבים של פונקציית התועלת הם תוצאה של תהליך קבלת החלטות אינדיבידואלית על ידי מודל AHP.

"מרחב התועלת המשותף"

את אוסף הפיתרונות האפשריים ניתן להציג במרחב דו-ממדי, שבו כל פיתרון מוגדר על ידי ערכי פונקציות התועלת של שני הצדדים. כאשר צדדים במשא ומתן מאופיינים על ידי אינטרסים מנוגדים, פיתרונות שמשיאים את פונקציות התועלת האינדיבידואליות רחוקים זה מזה. פתרונות יעילים נמצאים על ""חזית היעילות" (Pareto frontier), ומהם יש לבחור את הפתרון המוסכם. ה-NSS כולל מודל Nash למציאת פיתרון יעיל והוגן מבין הפיתרונות היעילים.

התקדמות איטרטיבית של משא ומתן

המיועד לעזור לצדדים לנהל משא ומתן מובנה ויעיל, וגם אלגוריתם לחיפוש פיתרונות המועדפים על ידי שניהם, שמספקים קריטריון (המוסכם הדדית) לחלוקה "הוגנת".

ב-NSS, משא ומתן בנוי כשילוב של שני תהליכים: תהליך קבלת החלטות אינדיבידואליות (Individual decision making) וחיפוש משותף של פיתרונות מועדפים (Joint problem solving). קבלת ההחלטות האינדיבידואלית מבוססת על גישה רב-קריטריונית, ומיועדת לעזור לכל צד בהבנת מערכת העדיפויות שלו בהקשר למשא ומתן. כל צד מגדיר פונקצית תועלת להערכת פיתרונות אפשריים למשא ומתן. זה נעשה על ידי אלגוריתם AHP (Analytic Hierarchy Process), שמסייע לכל צד בהבנת בעיית הקצאת המים המשותפים, על ידי חלוקתה למרכיביה הבסיסיים (מטרות אינדיבידואליות ופתרונות חלופיים), ובהבנת החשיבות היחסית של המרכיבים האלו.

התמיכה בחיפוש אחר פתרונות מועדפים הדדית (מתוך סט של פיתרונות אפשריים) נעשית על ידי יישום של מודלים למשחקי מיקוח, שיתופיים (פיתרון Nash) ולא שיתופיים (פרוטוקול המשחק "הצעות לסירוגין" ופיתרון בעל שיווי משקל של Nash) .

מרכיב מרכזי ב-NSS הוא מודל WAS שמסייע לצדדים בתהליך קבלת החלטות גם ברמה אינדיבידואלית וגם ברמה משותפת. כל צד יכול לבדוק תוצאות של תסריטים שונים (המבוססים על הנחה לגבי הקצאת המים מהמקור המשותף) להקצאת מים בתוך המדינה שלו (על ידי המודל המדינתי). בדרך הזו יכול כל צד לבדוק את התוצאות של פיתרונות חלופיים למשא ומתן שהוא מתכוון להציע, או פיתרונות המוצעים לו. בנוסף, הצדדים יכולים לנתח במשותף את הפיתרונות האזוריים המתייחסים למקור המים כ-"מאגר המשותפת" (common pool), ו/או כוללים העברת מים כלשהי בין שתי המדינות (ישויות).

<u>פרוטוקול של אינטראקציה</u>

ה-NSS כולל פרוטוקול אינטראקציה, המגדיר את השלבים (צעדים) הבסיסיים של משא ומתן. לפי הפרוטוקול, הצדדים מבצעים לסירוגין שני תהליכים – יצירת פיתרונות חלופיים וניתוחם. מטרתם של התהליכים אלה היא להוביל את הצדדים לכיוון הפיתרונות שמשפרים את ההישגים של שניהם כאחת. כל צד יכול להציע פיתרון ללא קשר או מחויבות להצעות קודמות. מודל WAS מסייע בתהליך יצירת הפיתרונות ובניתוחם, בכך שהוא מאפשר ניתוח חלופות שונות להקצאת המים בין הצדדים ובתוך כל אחת מהמדינות. תוצאות הרצת מודל WAS לכל פיתרון חלופי מנותחות על ידי כל צד באמצעות מודל AHP. הרחבת סט פיתרונות אפשריים (על ידי יצירת פיתרונות חדשים) והקטנתו (על ידי פסילת פיתרונות לא רלוונטיים) מתבצעים בצורה איטרטיבית, עד שהצדדים מגיעים לפיתרון יציב (או שהמו"מ נכשל, והם מסתלקים ממנו).

WAS – Water Allocation System: מודל אופטימיזציה להקצאת מים

הגישה הכלכלית מבוטאת במודל אופטימיזציה להקצאת מים – WAS (Fisher et al., 2002, 2005). האזור שעליו מופעל המודל מחולק לתת-אזורים, ובכל אחד שלושה מגזרים: חקלאות, עיר ותעשייה. הקלט של המודל כולל נתונים הידרולוגיים (כמויות מים זמינים ואפשרות להתפלת מי ים), נתוני תשתית קיימת (מערכת אספקת מים וחיבורי צרכנים), נתונים כלכליים (מאפייני פונקציות הביקוש של כל המגזרים בכל תת-האזורים, ועלויות הפקה ואספקה), מאפייני מדיניות אספקת מים (כמויות מינימאליות/מקסימאליות לאספקה לצרכנים ו/או להפקה ממקורות מים שונים, מדיניות להגדרת מחירי המים, וכד').

המודל מקצה מים לכל הצרכנים בכל תת-האזורים, במטרה להשיא את התועלת הכלכלית הנקייה (תועלות פחות עלויות) הכוללת של כלל הצרכנים בכל האזור. האופטימיזציה מתבצעת בכפוף לאילוצים הידרולוגיים, פיזיים, פוליטיים, אדמיניסטרטיביים ואחרים.

נתוני הפלט של המודל כוללים את כמויות המים האופטימאליות לאספקה, הרווח הכלכלי הכולל נטו משימוש במים, מחירי הצל של המים לכל הצרכנים בכל תת-האזורים ומחירי הצל של כל האילוצים במודל, כולל מחירי הצל של המים במקור.

מודל WAS אינו פועל על פי גבולות בינלאומיים, אלא על פי הגדרת האזור אשר בו מתקיימת הקצאת המים. זה יכול להיות חלק ממדינה, מדינה שלימה, או אזור שחלקיו במדינות שונות. את מקורות המים המשותפים למספר מדינות שכנות, ניתן להגדיר "כמאגרים משותפים" (common pools). במקרה זה, החלוקה האופטימאלית של מקורות המים הבינלאומיים מתקבלת כתוצאה של האופטימיזציה. אפשרות שנייה היא להגדיר ראשית את הקצאת המים מן המקור המשותף בין המדינות, ורק אז לבצע אופטימיזציה לאספקת מים בתוך כל מדינה בנפרד. בהתאם לכך, ניתן להפעיל את המודל במתכונת "אזור" או "מדינה". תוצאות הרצת המודל מוגדרות על ידי מכלול האילוצים (פיזיקליים, פוליטיים, אדמיניסטרטיביים, וכד') הנקבעים על ידי המשתמש/משתמשים. עבור כל מערך אילוצים יתקבלו כמויות המים לאספקה, ערכי ומחירי הצל של המים והרווח הכלכלי. כל מערך של אילוצים מייצג *תסריט* מסוים להקצאת המים, ובהתאם למודול של WAS התסריט הוא "אזורי" או "מדינתי".

NSS - מערכת תומכת משא ומתן

במחקר זה פותחה מערכת תומכת למשא ומתן (NSS) בין שתי מדינות (או ישויות פוליטיות) על מקורות מים משותפים. המערכת מתייחסת לשני הצדדים באופן סימטרי, ומספקת אותם כלים תומכי קבלת החלטות אינדיבידואלית לשניהם. המערכת כוללת את פרוטוקול האינטראקציה,

שניהם ביחד לנתח את ההשלכות של פיתרונות מוצעים, 3) הרחבת מרחב הפיתרונות החלופיים, 4) שינוי הדרגתי בעמדות של הצדדים (Attitudinal transformation of the parties), 5) בחירת פיתרון יעיל ו-"הוגן".

למרות שבמסגרת עבודה זו פותחה מערכת תומכת למשא ומתן בין שני צדדים, את אותם העקרונות ניתן ליישם גם למצבים רב-צדדיים. בכל אופן, הרחבה כזו דורשת התייחסות מיוחדת לאלמנטים המאפיינים את תהליכי משא ומתן רב-צדדיים, כמו למשל היווצרות קואליציות ואחרים.

<u>מסגרת העבודה</u>

תהליך משא ומתן מאופיין על ידי מספר מרכיבים ומאפיינים. בחירת המאפיינים הספציפיים למידול על ידי מערכת תומכת לקבלת החלטות תגדיר את האופן שבו המערכת תשפיע על התהליך ועל תוצאת המו"מ. אנו מחלקים את המאפיינים שנראים לנו כחשובים ביותר, ושאותם ניתן למדל, לשתי קבוצות:

א. מאפיינים החשובים מנקודת המבט המשותפת לצדדים המעורבים (סימטרייה, מוטיבציה ופרוטוקול/כללים של האינטרקציה בין הצדדים)

ב. המאפיינים החשובים מנקודת המבט העצמית של כל צד (מערכת עדיפויות אינדיבידואלית, אסטרטגיות, איכות התוצאה, התחייבות, אינפורמציה).

במידול מאפייני המו"מ על מים נעשה על ידי שילוב כלים מתורת קבלת ההחלטות ותורת המשחקים עם גישות כלכליות להקצאת מקורות במחסור (allocation of scarce resources), כפי שיפורט להלן.

<u>גישה כלכלית: ערך כלכלי של מים</u>

הערך הכלכלי של מים בא לכלל ביטוי בנכונות של צרכנים לשלם עבורם. נכונות זו הינה פונקציה של כמות המים: עבור הכמויות הראשונות, המיועדות לסיפוק צרכים בסיסיים, המחיר שמוכנים לשלם הוא הגבוה ביותר, והוא הולך ויורד עם כמויות מים נוספות, המיועדות לסיפוק צרכים פחות חשובים. תלות זו של המחיר בכמות מתוארת על ידי פונקציית ביקוש המאפיינת צרכן בודד, מספר צרכנים, מגזר מסוים (למשל החקלאות), או מדינה שלמה. רווח כלכלי נטו לצרכן (או לקבוצת צרכנים), משימוש בכמות מים מסוימת, שווה לשטח מתחת לפונקצית הביקוש עד לכמות זו, בניכוי עלויות אספקת מים.

ערך הצל של מים הוא ערכה של פונקצית ביקוש בנקודת הצריכה הקיימת; הוא מגדיר את המחיר הגבוה ביותר שהצרכן יהיה מוכן לשלם עבור יחידת כמות מים נוספת, אילו הייתה זמינה. בנקודת האספקה לצרכן, *מחיר הצל* של המים שהוא מקבל שווה למחיר הצל של המים במקורם (הנובע מהיות המקור מוגבל ומנוצל במלואו), בתוספת עלות הולכת המים עד לנקודת האספקה.

מערכת תומכת למשא ומתן על משאבי מים בינלאומיים במחלוקת

לאה קרונבטר

תקציר

משא ומתן על חלוקת מים ממקור בין-לאומי מתרחש בזירה מורכבת, הן בגלל ריבוי המטרות של כל אחד משני הצדדים, המושפעות מכמויות המים העומדות לרשותו, והן בגלל האינטרסים המנוגדים של הצדדים והעדר חוק או הסדר בין לאומי המכתיב או מציע פיתרון חד-משמעי לחלוקה הוגנת של מקורות המים המשותפים. מקורם של הרבה סכסוכים על מקורות מים בין-לאומיים הוא מחסור במים – קיים או צפוי (Gleick, 1993; Kliot et al., 1996). יש הוכחות שניהול מים לא יעיל (מחירי מים נמוכים הגורמים לבזבוז, שאיבת יתר, וכדי) עלול כשלעצמו לגרום למחסור מים (Fisher et al., 2002, Tietenberg, 1992, Jordan 1999). מאידך, יש בסיס לטענה, שעקרונותיה של כלכלת השוק החופשי יכולה לשפר את יעילות השימוש במים. לפי גישת השוק, הקצאת מים יעילה מתקבלת על ידי סחר חופשי במים, שעשוי להביא רווחים משמעותיים (לפחות כלכליים) לכל הצדדים המעורבים. עם זאת, הוכח כבר, שבגלל סיבות רבות אי אפשר ליישם את העקרונות של שוק חופשי כמות שהם על השימוש במים , שכן למים ישנם ערכים נוספים מעבר לערך הכלכלי, ערכים תרבותיים, דתיים, היסטוריים, ומעל לכל, ערכים אסטרטגיים וביטחוניים. לכן, משא ומתן בין ישויות פוליטיות שכנות על חלוקת משאבי מים משותפים צריך לכלול התייחסות למיגוון מטרות, ולאפשר לצדדים להביאם לכלל ביטוי, תוך כדי תהליך של אינטראקציה ביניהם ולימוד הדדי.

בעבודה זו פותחה מערכת תומכת משא ומתן על מקורות מים בין-לאומיים (Negotiation Support System, להלן NSS), המשלבת מודל אופטימיזציה להקצאת מים המבוסס על עקרונות כלכליים, עם כלים תומכי קבלת החלטות וכלים של תורת המשחקים.

<u>מטרת המחקר</u>

מטרת המחקר היא לפתח מערכת תומכת למשא ומתן לצדדים שמייצגים ישויות עצמאיות פוליטית, אשר להן דרישות על מקור מים משותף. בחלק ניכר מן המקרים הידועים בעולם, מטרתם של הצדדים למשא ומתן על מקור מים בין-לאומי היא להבטיח לעצמם כמה שיותר ממקור המים. אינטרסים אלה מנוגדים ביסודם, ולכן בדרך כלל המו״מ מתנהל כתהליך מיקוח (משחק סכום-אפס), מלווה בחוסר אמון הדדי ותקשורת גרועה, כך שלצדדים ישנם קשיים בזיהוי פיתרונות מועדפים הדדית.

אי לכך, מטרת המחקר הינה לפתח מערכת שתסייע לצדדים להתקדם ממיקוח *דיסטריבוטיבי*, המבוסס על דרישת זכויות או על כוח, לכיוון משא ומתן *אינטגרטיבי*, שיוביל את הצדדים לפיתרון מועיל לכל המעורבים (win-win solution). ההנחה של המחקר היא שכדי לאפשר תנאים למשא ומתן אינטגרטיבי, המערכת אמורה לתמוך בתהליכים הבאים: 1) הבנה והצגה מובנית של הבעיה על ידי כל אחד מן הצדדים עבור עצמו (Individual structuring of the problem), 2) יכולת של כל צד לחוד ושל

רשימת איורים

רשימת טבלאות

תוכן העניינים

הבעת תודה

המחקר נעשה בהנחיית פרופ׳ אורי שמיר ביחידה להנדסת סביבה, מים וחקלאות, הפקולטה להנדסה אזרחית וסביבתית.

אני מודה לטכניון על התמיכה הכספית הנדיבה בהשתלמותי.

ברצוני להודות לפרופסור אורי שמיר על שנתן בי את אמונו בעבודה על מחקר זה, כמו גם על עזרתו, עצתו ותמיכתו לכל אורך הדרך. פרופ׳ שמיר סיפק לי תמיד את מיטב התנאים והאמצעים ללימוד ולעבודה המדעית. הנני מבקשת להודות לו על עצותיו המועילות ועל השיחות המדעיות, בייחוד ברגעים המאתגרים במהלך המחקר. מעל ומעבר להדרכתו המלומדת, פרופ׳ שמיר שימש לי כמורה דרך. ידיעותיו הרחבות ואישיותו טבעו בי את חותמם, הן כבעלת מקצוע והן כאדם.

אני מודה לגב׳ יונה שמיר, מנהלת המרכז הישראלי למשא ומתן וגישור (ICNM), על שהזמינה אותי ונתנה לי הזדמנות להשתתף בסדנה ״בניית קונצנזוס״. אני מודה גם לחברי הסגל של ICNM, גב׳ יעל פלר, גב׳ נוני טל ומר׳ יונתן קוברסקי, על שאפשרו לי לבצע חלק מהניסויים במרכז, וגם על עזרתם, סבלנותם ומסירותם במהלך הניסויים.

תודתי למגשרים ממרכז ICNM, לסטודנטים בטכניון, וכן למר שאול ארלוזורוב ולד״ר ענאן ג׳איוסי, שהשתתפו בניסויי הסימולציה לבחינת המערכת שפותחה.

אני אסירת תודה לפרופסור איילה כהן על זמנה ועל תרומתה לניתוח הסטטיסטי של תוצאות הניסויים. עצותיה הגדירו בעבורי את הכיוון הנכון ברגע שמבחינתי היה הקשה ביותר במחקר. תודה גם לפרופ׳ נעמי כרמון, שסייעה בעצה על השאלונים וניתוחם.

ברצוני להודות למשפחתי על הבנתם וסבלנותם לכל אורך הדרך. תודה מיוחדת לאמי, שממנה ירשתי את תאוות הדעת, על תמיכתה בכל בחירותי.

מוקדש לזכרו של אבי

מערכת תומכת למשא ומתן על משאבי מים בינלאומיים במחלוקת

חיבור על מחקר

לשם מילוי חלקי של הדרישות לקבלת התואר
דוקטור לפילוסופיה

לאה קרונבטר

הוגש לסנט הטכניון – מכון טכנולוגי לישראל

סיון תשס"ה   חיפה   יולי 2005

מערכת תומכת למשא ומתן על משאבי מים בינלאומיים במחלוקת

לאה קרונבטר