Modeling and Analysis of Multilateral Negotiations

by

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

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Abstract

The modeling and analysis of multilateral negotiations are studied under the assumption that reaching an agreement is the main objective of the negotiators. A new methodology and associated definitions are proposed to predict the outcomes of such negotiations. The general objective of the new methodology is to study movements from one state to another in multilateral negotiations, to predict stable agreements, and to study their properties. The assumptions that the set of possible agreements is discrete and specified in advance make the negotiation problems considered here distinctive. Each decision maker has two concerns: first, achieving an alternative that is as preferable as possible; second, building support for this alternative among the other decision makers. In summary, this research consists of a systematic investigation of multilateral negotiations with the following general characteristics:

- Decision makers in the negotiation seek a resolution that is not only feasible but also stable (enduring). Of course, each negotiator tries to attain the most preferable agreement for himself or herself.
- If an agreement is reached, it must be an alternative from a pre-specified list, and all of the decision makers must accept the agreement.
- Decision makers can possess different levels of power (or legitimacy) in support of an agreement, so the negotiation is not necessarily symmetric.

Moreover, the analysis makes use of the decision makers' preference orders over the proposed alternatives only, and does not require cardinal representations of their preferences.

New concepts including *State, Acceptability, Feasibility, Stability,* and *Fallback Distance* are defined to pave the way for the proposed methodology. It is based on four types of movements, from unstable states toward stable ones, including *preferential improvement, agglomeration, disloyalty move*, and *strategic disimprovement*. Some criteria and algorithms are proposed to measure the likelihood of different moves and different outcomes. An important theorem shows that all four types of movement are mutually exclusive. The evolution of a negotiation from its status quo to the most likely outcomes is illustrated, using a tree. Several applications demonstrate that the proposed methodology can be applied to

identify the most likely outcomes of a multilateral negotiation. Sensitivity analyses can be applied in several different ways to assess whether sudden or unforeseen changes in the model affect the conclusions.

Several methods can be used from the literature for predicting the outcome of a negotiation. Social Choice Rules, Fallback Bargaining Procedures, and Bankruptcy Solutions are applied to the current negotiations over the legal status of the Caspian Sea to predict or recommend the most appropriate resolution among the proposed alternatives. In addition, the applicability of Graph Model for Conflict Resolution and its associated decision support system (DSS), GMCR II, are briefly discussed. Reasons why these methods are not appropriate when reaching an agreement is the main objective of decision makers (DMs) are then put forward.

Based on the conceptual model for multilateral negotiations proposed in this thesis, a practical Negotiation Support System (NSS) is designed and implemented in Microsoft Access using Microsoft Visual Basic. This NSS increases the speed and accuracy of calculations. In the output of this NSS, all movements from initial states to subsequent states and their associated likelihoods are clearly illustrated, and all stable agreements are distinguished.

Two real-world multilateral negotiations, over the legal status of the Caspian Sea and over the Epton site brownfield redevelopment project in Kitchener, Ontario, Canada, are modeled and analyzed using the proposed methodology. To measure DMs' weights quantitatively in the Caspian Sea negotiations, eleven criteria that can be considered to be important determinants of countries' capabilities are discussed, evaluated, and integrated using a Multiple Criteria Decision Analysis model. The Data Envelopment Analysis (DEA) method is employed to find the most favourable set of relative importance of different criteria for each country. Applying the proposed methodology indicates that unanimous agreements over the division of the Caspian Sea, either based on the International Law of the Seas or based on Soviet maps, are most likely as the enduring legal status of the Caspian Sea.

The objective of applying the proposed methodology to actual negotiations over the redevelopment of a brownfield project is to ensure that the new methodology is flexible enough to model more real-world cases. Moreover, we wanted to test how well the actual outcomes of the real world negotiations match the most likely outcomes identified by the

methodology. The results show that the decisions on the use of the Epton site followed the most likely path described and predicted by the model.

This thesis is multidisciplinary in nature. It utilizes different branches of knowledge, including applied mathematics (game theory), computer science and programming, international relations, and environmental management. However, negotiation modeling and analysis in this thesis is developed from a systems engineering perspective.

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Finally, my wife deserves the highest level of praise and gratitude. I appreciate Fatemeh for her encouragement, understanding, and patience.

Dedication

To my parents and my wife

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Abbreviations

AG	Agglomeration
AP	Adjusted Proportional
BTC	Baku – Tblisi – Ceyhan
CEA	Constrained Equal Award
CPM	Condorcet’s Practical Method
CS	Compromise Set
DEA	Data Envelopment Analysis
DL	Disloyalty Movement
DM	Decision - Maker
ERD	Entity Relationship Diagram
FB	Fallback Bargaining
FD	Fallback Distance
GMCR	Graph Model for Conflict Resolution
GMR	General Meta Rationality
MC	Majoritarian Compromise
MVR	Median Voting Rule
NSS	Negotiation Support System
PI	Preferential Improvement
SD	Strategic Disimprovement
SEQ	Sequential Stability
SMR	Symmetric Meta Rationality
TU	Transferable Utility
UNCLOS	United Nations Convention on the Law of the Sea

Chapter 1

Introduction

Negotiation is joint decision making in which divergent positions are ultimately combined under conditions of conflict and uncertainty, into a single outcome (Zartman and Rubin, 2003). Of course, negotiations may break down short of a resolution. Two or more individuals or groups are involved, and they make decisions and engage in exchange of information in order to determine a compromise, or perhaps a solution “outside the box”. Kersten (2002) defines negotiation as “a process of social interaction and communication that involves the distribution and redistribution of power, resources, and commitments.”

1.1 Motivation

During the past few decades, many approaches and models of the negotiation process have been proposed, based on different assumptions and principles, with different objectives. Nonetheless, there are only two fundamental approaches to the theory and practice of negotiation:

• Positional negotiation, also called contentious or competitive negotiation; and

• Integrative negotiation, also called cooperative problem solving or group decision making.

Positional negotiation is often referred to as *hard* bargaining, while integrative negotiation is *soft*. Hard bargaining focuses on winning, avoids compromise, may include hidden agendas, and may result in one-sided agreements. In contrast, soft bargaining is adaptable, focuses on finding win/win solutions, encourages compromise, and sometimes creates innovative solutions (Fisher *et al.*, 1991)

In general, this research falls within the first category, but seeks to integrate ideas from both. In this research, a new methodology is developed to model and analyze multilateral negotiations. Aiming to model negotiations over the legal status of the Caspian Sea, the author was motivated to focus on the negotiations outside the competitive and cooperative approaches. Caspian Sea negotiations cannot be classified under a purely non-cooperative approach because decision makers in these negotiations are seeking a stable or enduring agreement whereas in a non-cooperative game, each player's main concern is to select his or her own strategy which may include continued disagreement. A feasible resolution for the legal status of the Caspian Sea entails long-term cooperation. The countries around the Caspian Sea have been persuaded to cooperate with each other in order to resolve the increased pollution of the Caspian Sea, and environmental problems like overfishing and poaching. On the other hand, the Caspian Sea negotiations are not cooperative in the conventional sense since there is no compromise. In other words, unlike the bargaining problem in the cooperative approach we have a discrete space of negotiations and the ultimate agreement must be an alternative from a pre-specified list. Hence, the author developed new definitions and methodology to model and analyze negotiations in competitive situations, when reaching agreement is a crucial issue for decision makers.

1.2 Problem Statement

One can distinguish two classes of games, called non-cooperative and cooperative. In non-cooperative games, all aspects of the players' interactions are included in the model. When studying non-cooperative games, one often assumes that the players are unable to communicate, treating players isolated as individuals acting explicitly in their own interests. Of course, their interests may be conflicting or coincident, or a mixture of the two. In cooperative games, players can not only communicate but also have a reliable and costless enforcement mechanism, enabling them to make binding agreements. In cooperative games, the question is how the players compromise. In other words, how they should share the gains of the cooperation. In the real world, most human interactions are not at either extreme – they lie somewhere between non-cooperative and cooperative approaches.

The methodology proposed in this thesis has some similarities with game-theoretic approaches conceptually, but differs from those approaches in some features. It is distinctive from non-cooperative games as decision makers in our model look only for possible agreements. On the other hand, it is different from cooperative games because the outcome of negotiations is assumed to be selected from a pre-specified discrete set of alternatives. Another difference is that game theory is based on Neumann-Morgenstern utilities which are cardinal values, while in the methodology proposed in this thesis one needs to know only the ordinal preferences of decision makers over the proposed alternatives.

New definitions and methodologies are proposed in this thesis to model and analyze multilateral negotiations with the following general characteristics:

- Decision makers in the negotiation look for a feasible resolution, in other words, a stable or enduring agreement. Of course, each negotiator tries to attain the most preferable agreement for himself or herself.
- If an agreement is reached, it must be one alternative from a pre-specified discrete list, which all decision makers must accept.
- Decision makers can possess different levels of power (or legitimacy) in support of an agreement, so the negotiation is not necessarily symmetric.

Moreover, only the preference order of each decision maker over the proposed alternatives is known for certain, so cardinal values cannot be assumed.

One common classification of models is as normative, descriptive or prescriptive. However, this categorization is not exclusive, and one cannot necessarily ascribe a given model or methodology to only one category. The methodology proposed in this research is mostly descriptive in the sense that the most likely outcomes of a multilateral negotiation are identified.

1.3 Structure of the Thesis

The remainder of this thesis is organized as follows. In Chapter 2, some of the most common negotiation models are introduced and applied to the continuing negotiations over the Caspian Sea. At the beginning of this Chapter, we review the history and geography of the Caspian Sea region and the history of multilateral negotiations over its legal status. Then, we briefly sketch the options for resolution for the legal status of the Caspian Sea, and discuss the five states' preferences among the alternatives. Our primary aim is to describe the negotiations and predict what the outcome will be. Nonetheless, we use some normative methods; many of our calculations are based on theories that assume that all bargainers act in their own best interests. In some sense, normative means doing what “should” be done, and what we do is similar to using game theory models to predict outcomes of conflicts. We discuss some selected social choice rules and apply them to find the “socially optimal” resolution. Subsequently, we review Fallback Bargaining and apply several versions of it to the negotiation scenario to predict the outcome of the bargaining. Next, we show how to represent the dispute in financial terms and apply several well-known fair division procedures called bankruptcy procedures. Finally, we discuss the limitations of the existing models including the Graph Model for Conflict Resolution. We explain why these models are not applicable when reaching an agreement is the main objective of decision Makers (DMs) in asymmetric multilateral negotiations.

Chapter 3 is devoted to proposing a new methodology to model and analyze multilateral negotiations with a specific structure. The negotiation problems modeled in this chapter are distinctive because the set of possible agreements is discrete and specified in advance. Each DM has two concerns: first, achieving an alternative that is as preferable as possible to himself or herself; second, building support for this alternative among the other DMs. The main objective of this development is to formulate methodologies to predict the most likely outcomes of a particular form of multilateral negotiation, based on the capabilities of the DMs and their preferences over the available alternatives. In addition, we determine to what extent a state is likely to occur as the outcome of the negotiation. Some cases of sensitivity analysis are subsequently applied to assess whether sudden or unforeseen changes in the model do not affect the conclusions of stability analyses.

In Chapter 4, we explain how our negotiation support system (NSS) is designed and implemented to represent the new conceptual definitions and run the proposed algorithms automatically. This Negotiation Support System is implemented in Microsoft Access using Microsoft Visual Basic.

In Chapter 5, we apply the proposed methodology for modeling and analysis to the multilateral negotiations over the legal status of the Caspian Sea. An investigation of the Caspian Sea negotiations is used to verify to what extent the proposed methodology can predict the observed outcomes of the negotiations. Then, we apply it to the ongoing negotiations to identify the most likely outcome of the continuing multilateral negotiations.

Chapter 6 concentrates on application of the proposed methodology to the modeling and analysis of actual negotiations over the redevelopment of the Epton site, a brownfield in Kitchener, Ontario. The objective is to ensure that the new methodology is flexible enough to model a range of real-world cases. The results show that the actual outcome of the negotiations over this redevelopment project matches the most likely outcome identified by the methodology. Chapter 7 concludes the thesis with a summary of the original contributions and promising directions for future research.

Chapter 2

Existing Models for Multilateral Negotiations

In this Chapter, we identify techniques for predicting the outcome of a negotiation and then apply them to the current negotiations over the legal status of the Caspian Sea. The objective is to demonstrate how the existing models can be used for the analysis of real-world negotiations. Moreover, we want to illustrate the capabilities and limitations of these methodologies in modeling a relatively complex case. Subsequently, we explain why these models are not entirely satisfactory when reaching an agreement is the main objective of DMs in asymmetric multilateral negotiations.

We discuss some social choice rules and review various versions of Fallback Bargaining, and then apply them to predict the outcome of the Caspian Sea negotiations. Then, we describe and apply bankruptcy procedures to find some fair divisions of the wealth of the Caspian Sea seabed. Finally, we discuss whether the Graph Model for Conflict Resolution can be applied for these purposes.

2.1 The Caspian Sea Negotiations

Since the existing models and the proposed methodology are applied to the Caspian Sea negotiations in this Chapter and in Chapter 5, respectively, a background of these negotiations is explained here in advance.

2.1.1 Background of the Caspian Sea negotiations

The Caspian Sea, which lies between the Caucasus Mountains and Central Asia, is considered by some to be the largest lake in the world. A salt-water body with an area of 376,000 km^2, it is more than four times larger than Lake Superior (82,414 km^2), the largest of the Great Lakes of North America. The Caspian Sea is the subject of one of the world's most intractable disputes, involving five littoral states. Figure 2.1 shows the location of the Caspian Sea, Azerbaijan, Kazakhstan, and Turkmenistan as well as the adjacent parts of Russia and Iran.

Figure 2.1: Map of the Caspian Sea region. - Source: the US Government (2006).

Perhaps one reason why the status of the Caspian Sea is so difficult to resolve is that the options are quite clearly specified and the disputants' preferences well known. Simply put, the issue is who owns which part of the Caspian Sea, or whether the five littoral states share the entire sea in some sense. The main attraction is the existence of immense amounts of petroleum in the seabed. The proven and suspected reserves total 201 billion barrels of oil and about 570 trillion cubic feet of natural gas (British Petroleum, Statistical Review of World Energy, 2004).

One additional issue is related to pipeline transit opportunities, such as the planned BTC (Baku-Tbilisi-Ceyhan) project, depicted in Figure 2.2, which will primarily benefit Georgia and Turkey, at a cost of US$3.6 billion. Another issue is geopolitical: Because it is a "crossroads" region, control of the Caspian Sea basin is important strategically, and both the USA and Russia have attempted to cooperate militarily with the newly independent states around the Caspian Sea (Kaliyeva, 2004). It was recently argued that the Caspian-Black-Mediterranean axis could have great potential for force projection by the USA (Muresan, 1998).

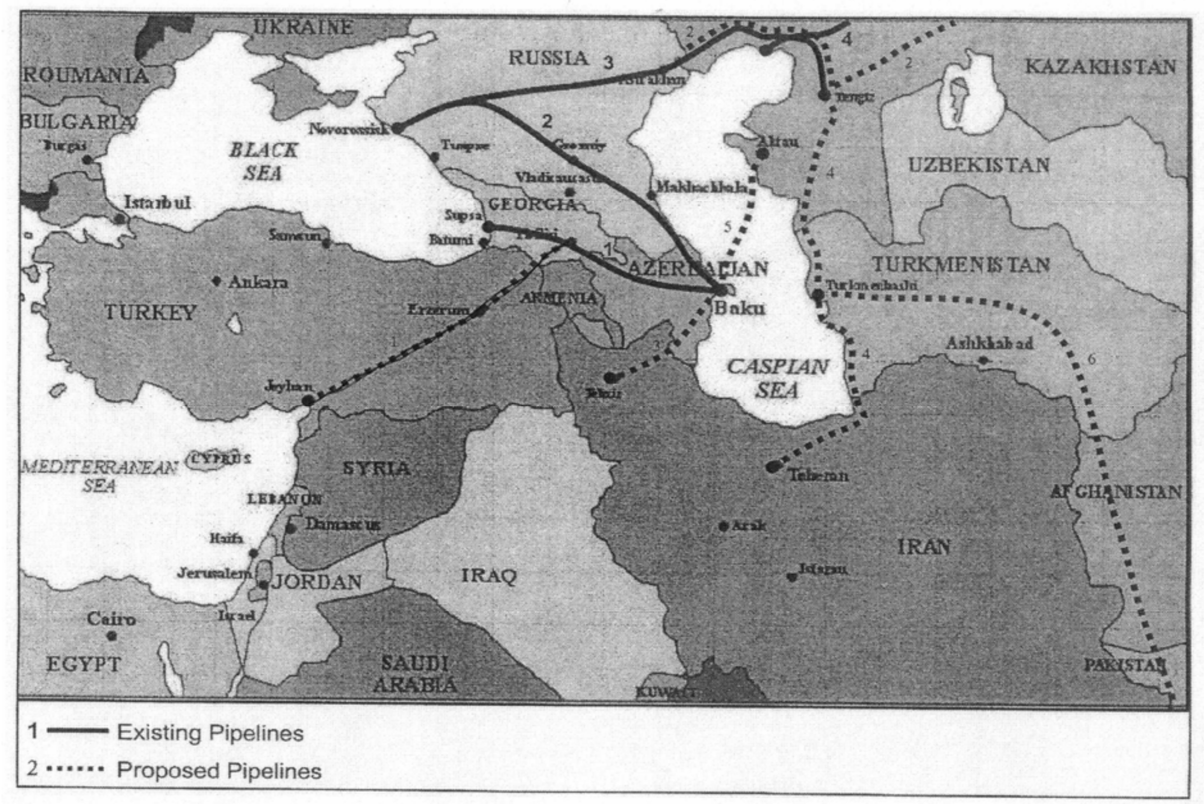

Figure 2.2: Map of the Caspian Sea and surrounding regions showing the existing and proposed pipelines (Rabinowitz *et al.*, 2004)

Unfortunately, these issues will remain unresolved until the legal status of the Caspian Sea, which has been unclear since the collapse of the Union of the Soviet Socialist Republics (USSR) in 1991, is settled. The consequences of this quagmire include increased pollution of the Caspian Sea, mainly by petroleum production and transportation; environmental degradation, due to overfishing and poaching; and an atmosphere in which regional cooperation is difficult or impossible (Caspian Sea Region: Environmental Issues, 2003).

Before the collapse of the Soviet Union, the Caspian Sea was shared by the USSR and Iran, which enjoyed a stable relationship. Two USSR–Iran treaties governed the Caspian Sea, one that guaranteed free navigation to both parties and one that extended each state's territorial waters 10 miles from the shoreline. Each state was granted exclusive fishing rights within its territorial waters under the latter treaty.

After the collapse of the USSR at the end of 1991, there were five littoral states bordering the Caspian Sea: Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. The legal status of the Caspian was immediately disputed, and no division of the waters or the seabed has been agreed upon to date. In addition to the important strategic issues associated with the stalemate, energy prices are rising and the consequences of having no agreement are mounting. The locations of the oil and gas fields in the Caspian Sea are illustrated in Figure 2.3.

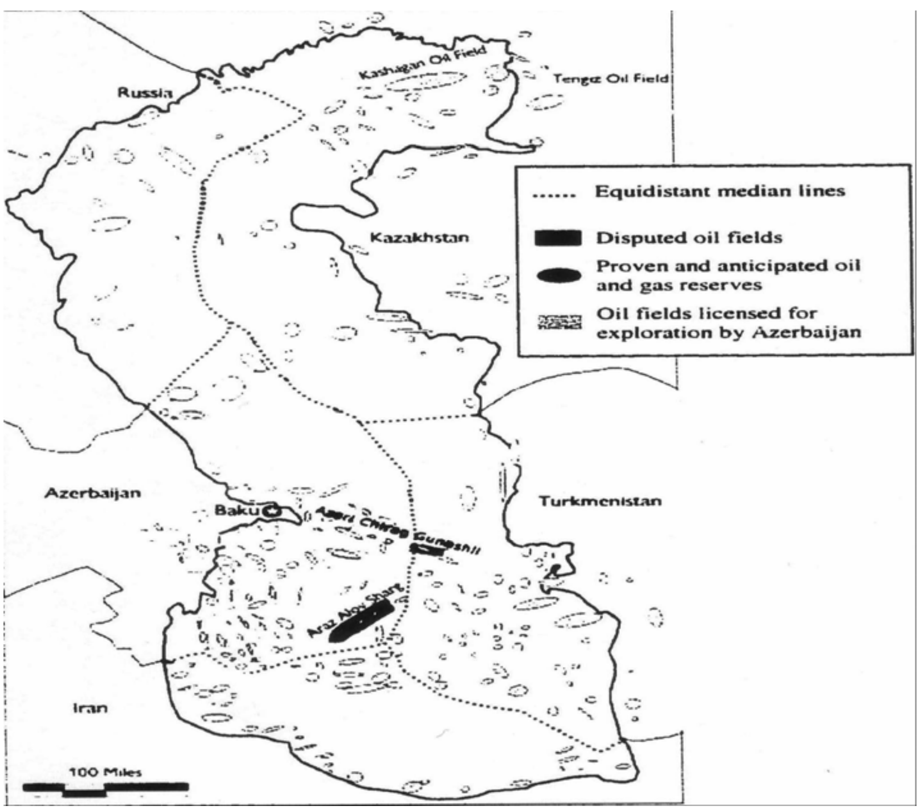

Figure 2.3 - Oil and gas fields in the Caspian Sea[1]
Source: (Eurasia Net, 2001)

[1] Division in this map is based on equidistant median lines.

From 1992 to 2007, the five littoral states met on 26 occasions, at the presidential, ministerial and expert levels, in all five states and in many different cities. The last presidential meeting was held in October 2007 in Tehran; another meeting took place in Moscow in February 2006.

The following factors contribute to the continuing difficulty in resolving the disagreement over the legal status of the Caspian Sea and the division of its waters and its oil-rich seabed:

• The number of disputants is relatively large, and their interests are quite different.

• Many external parties have an interest in the region, including world powers like the USA and China, regional powers like Turkey, and oil industry multinational companies.

• The ownership of the Caspian Sea is complicated by the fact that its geographical classification is ambiguous; international law does not clarify whether it is a lake or a sea.

The main point of contention among the five littoral states is whether to apportion the sea or treat it as a whole. Some would prefer to divide it into discrete national segments while others would like to introduce a "condominium regime" under which the Caspian would be jointly owned, with no state having exclusive control over any part of it (Ahmadov, 2002). Iran and Russia, which possess other economic resources, generally favor the condominium principle; Azerbaijan and Kazakhstan, and to a lesser extent, Turkmenistan, favor exclusive economic zones, within which a state would be able to conduct operations without the consent of the others. These countries clearly anticipate that harvesting the rich resources of the Caspian seabed will be a great boon to their national development. However, they will have no control over any of the seabed resources until there is an agreement in place that accords each littoral state an exclusive economic zone.

International law does not definitively settle the geographic status of the Caspian Sea (Witt, 2000). If the Caspian Sea is a lake, then under international rules condominium status should apply, and sovereignty should be jointly held. But the Caspian Sea cannot readily be classified as an "international lake." First of all, its vast size and oceanographic characteristics are typical of seas rather than lakes. Second, and more importantly, the Caspian is now surrounded by a relatively large number of countries, which complicates matters. By contrast, the Great Lakes of North America are surrounded by only two countries, the USA and Canada, and the Gulf of Fonseca is bordered by only three, El Salvador, Honduras, and Nicaragua.

The international rules regarding seas, particularly the United Nations Convention on the Law of the Sea (UNCLOS), could be applied to the Caspian if it were classified as a sea (Janusz, 2005). Full maritime boundaries of the five littoral states could then be established based on the median lines from the shores of the littoral states, using the principle of equidistance to divide the sea, and the undersea resources could be split into national sectors. This approach is referred to as "sectoral division."

The deadlock among the parties had solidified by 1997. Then Russia changed its priorities in an apparent effort to become more pragmatic and constructive. Rather than continuing to oppose the de facto alliance of Azerbaijan, Turkey, and the USA, Russia started to cooperate with all of the other littoral states by promoting mutually beneficial projects in the energy sphere. It further suggested that the two historical treaties with Iran (dating from 1921 and 1941) were still valid. At the same time, despite the fact that division of the seabed was not mentioned in the existing treaties, it argued that the seabed should be divided among the five littoral states according to the modified median line method. Russia's new negotiating strategy may reflect a desire for oil pipelines to be located on Russian soil.

Iran initially rejected a division of the Caspian Sea based on the median line method, which would give it a share of only 13.6%. Feeling isolated in its stance and lacking the power to overcome the positions of the other states, it proposed two conditions for the division of the sea. In 2000, Khatami, the President of Iran at the time, demanded that Iran's share be no less than 20% and that its sea surface and seabed areas be superjacent.

Russia and Turkmenistan accepted Iran's proposition at first, but Azerbaijan and Kazakhstan objected. Then Russia changed its position to advocate a dual purpose regime, in which division of the seabed and condominium status of the surface would produce a solution more acceptable to Azerbaijan and Kazakhstan. Another proposal that was aired at this time was to divide the Caspian Sea based on Soviet-era maps. This system, based on the extension of the internal borders of five Soviet Republics, Azerbaijan, Turkmenistan, Kazakhstan, Dagestan, and Kalmykia, was developed by Moscow as an aid for administering Caspian Sea oil exploration projects after the Second World War (Maleki, 2001).

Since five years ago, there have been some negotiating meetings among the officials of the five littoral countries, but there have not been any significant changes in their positions. This is the situation that we will attempt to model and analyze in Chapters 2 and 5.

2.1.2 The Options and the States' Preferences

The five coastal states – Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan – entered negotiations in 1993, but have not yet agreed upon who owns the waters or the oil and natural gas beneath them. Based on the history of the negotiations explained in Section 2.1.1, there are five ways to resolve the legal status of the Caspian Sea. We denote these alternatives as follows:

C: Condominium status for both the surface and the seabed

D_m: Division based on the International Law of the Seas

D_e: Equal Division: 20% of the sea, and the seabed, to each littoral state

D_s: Division based on Soviet maps

DC: Division of the seabed based on the International Law of the Seas, with condominium status on the surface

It is important to note that "Equal Division" does not result in equal shares in the revenue. Each state would receive 20% of the total surface (and seabed) of the Caspian Sea located adjacent to its shores. Since oil and gas resources are not uniformly distributed across the sea, the distribution of resources among states would be unequal. In contrast, the condominium alternative proposes that each state simply receive an equal share of the total revenue from joint exploitation of the resources.

Based on assessments of their national economic, political, and military interests, and on their public statements, it is possible to infer that each state has strict preferences among the five alternatives. These preferences are indicated as follows (where ">" means "strictly prefers"):

Azerbaijan **:** $D_s > D_m > DC > D_e > C$

Iran **:** $C > D_e > D_m > DC > D_s$

Kazakhstan **:** $D_s > D_m > DC > C > D_e$

Russia **:** $C > DC > D_s > D_m > D_e$

Turkmenistan: $D_e > D_s > D_m > DC > C$

For convenience's sake, a matrix will be used in which each state has a row listing the alternatives from most to least preferred. There are n = 5 rows and k = 5 columns.

$$\begin{array}{l} \text{Azerbaijan} \\ \text{Iran} \\ \text{Kazakhstan} \\ \text{Russia} \\ \text{Turkmenistan} \end{array} \begin{pmatrix} D_s & D_m & DC & D_e & C \\ C & D_e & D_m & DC & D_s \\ D_s & D_m & DC & C & D_e \\ C & DC & D_s & D_m & D_e \\ D_e & D_s & D_m & DC & C \end{pmatrix}$$

2.2 Social Choice Procedures

Social choice theory is concerned with the principles underlying group choice by individuals who have different preferences among the available options [Roberts, 2006]. It deals with the principles of aggregation of preference in the sense that individual preference is to be reflected equitably in group preference insofar as possible. Social choice theory is applicable to decision-making by committees, voting, and many aspects of welfare economics. A social choice rule (SCR) selects a subset from a larger set of possibilities based on the configuration of individual preferences among the possibilities and other characteristics. We now discuss some common social choice rules and employ them to find the "socially optimal" legal status for the Caspian Sea.

2.2.1 Condorcet Choice

A Condorcet winner is an alternative that is at least as preferable as every other alternative for a majority of participants [Young, 1995]. For example, D_m is preferred to C by Azerbaijan, Kazakhstan, and Turkmenistan, while C is preferred to D_m by Iran and Russia. Therefore, D_m is at least as preferable as C for a majority. Because we have assumed strict preferences, and since there is an odd number of participants (five), there must be a majority preference between any two alternatives. The entries in the table below show the winning alternative in pairwise comparison between the row alternative and the column alternative.

Table 2.1: Majority preference between all possible pairs of distinct alternatives

Alternatives	C	D_m	D_e	D_s	DC
C	-	D_m	C	D_s	DC
D_m	D_m	-	D_m	D_s	D_m
D_e	C	D_m	-	D_s	DC
D_s	D_s	D_s	D_s	-	D_s
DC	DC	D_m	DC	D_s	-

It follows from Table 2.1 that D_s is a Condorcet winner because it wins every comparison. Similarly, D_e is a Condorcet loser since it loses in pairwise comparison to every other alternative. In some social choice scenarios, there is no Condorcet winner, but there is one in this problem.

As a kind of sensitivity analysis, we note that different solutions might arise if the preferences were slightly different. Suppose that we change the preference orders of Kazakhstan and Russia slightly but keep the preference orders of the other states the same. Specifically, if Kazakhstan and Russia were mostly concerned about the economic profit that could be obtained from exploitation of the Caspian Sea's oil and gas resources and ignored their political and perhaps military interests, then we could consider the following preference orders for them (see Tables 2.5, 2.6, and 2.7):

Kazakhstan: $D_s > D_m > DC > D_e > C$

Russia: $C > DC > D_e > D_s > D_m$

In contrast to the previous results displayed in Table 2.1, no Condorcet winner emerges under the new configuration of the states' preferences. Also, alternative *C* (Condominium) becomes the Condorcet loser under the new conditions.

2.2.2 Borda Scoring

Another well-known social choice rule is the Borda Score [Young, 1995], which is defined for *m* alternatives as follows: assign score $m - 1$ to a participant's most preferred alternative, score $m - 2$ to the participant's second most preferred alternative, and in general score $m - i$ to the participant's i^{th} most preferred alternative. (In other words, the score assigned by a DM to an alternative is the number of other alternatives it is preferred to.) The Borda Score of an alternative is the sum of the scores assigned to it by all participants. The alternative(s) with the highest total score defines the choice set for the Borda social choice rule.

Table 2.2: Borda Score assignment of the alternatives

Bargainers / Alternatives	Iran	Russia	Turkmenistan	Azerbaijan	Kazakhstan	Total score
C	4	4	0	0	1	9
D_m	2	1	2	3	3	11
D_e	3	0	4	1	0	8
D_s	0	2	3	4	4	13
DC	1	3	1	2	2	9

According to the Borda Score, D_s is the best choice.

2.2.3 The Plurality Rule

The Plurality Rule is an old and rather simplistic way of making a social choice. It selects the alternative(s) considered best by the most voters (Merlin and Sanver, 2006). In other words, it assigns a score of 1 to a party's most preferred alternative, 0 to all other alternatives, and selects the alternative(s) with the greatest total score. The method is most dependent on first-choice support, disregarding any lower-level (or "lower-quality") support. The total plurality scores of all the alternatives in our case study are as follows:

$C = 2$, $D_s = 2$, $D_e = 1$, $DC = 0$, $D_m = 0$

Thus, the plurality SCR recommends either C or D_s as the optimal legal status alternative for the Caspian Sea.

2.2.4 Median Voting Rule and Majoritarian Compromise

Another social choice rule is the Median Voting Rule (MVR) proposed by Bassett and Persky (1999). This rule picks all alternatives receiving majority support at the highest possible level.

Since there are five littoral states involved in the Caspian Sea negotiations, majority support means having the support of at least three states.

A decision maker supports an alternative at the j^{th} level if the alternative is in position j, or higher, in the DM's preference order. In Table 2.3, level 1 is the highest possible level. Table 2.3 shows that no alternative receives majority support at level 1, that alternative D_s receives majority support at level 2, and that no other alternative receives majority support at that level. Hence, the Median Voting Rule picks D_s as the legal status of the Caspian Sea.

Table 2.3: The number of supporters for each alternative at each possible level of support

Alternatives	Support level				
	Level 1	Level 2	Level 3	Level 4	Level 5
C	2	2	2	3	5
D_m	0	2	4	5	5
D_e	1	2	2	3	5
D_s	2	3	4	4	5
DC	0	1	3	5	5

Like the Median Voting Rule, the Majoritarian Compromise (MC), which was introduced and developed by Sertel and Yilmaz (1999), picks alternatives receiving majority support at the highest possible level, but ties are broken according to the level of support received by the alternatives that are tied. Hence, Majoritarian Compromise is a refinement of Median Voting Rule, in the sense that the set of alternatives selected by Majoritarian Compromise is a subset of the set of alternatives chosen by the Median Voting Rule. Like the Median Voting Rule, the Majoritarian Compromise rule selects D_s as the legal status of the Caspian Sea.

2.2.5 Condorcet's Practical Method

Condorcet's Practical Method (CPM), described by Nurmi (1999), picks the alternative receiving a majority support at level 1, whenever it exists. If there is no alternative with majority support at this level, then the alternative(s) receiving the highest support at level 2 is chosen. Table 2.3 shows that there is no alternative with majority support (at least three) at the first level but that a majority of states (3) support D_s at level 2. Therefore, Condorcet's Practical Method selects D_s as the optimal legal status for the Caspian Sea.

2.2.6 Conclusions

In summary, all of the above-mentioned social choice procedures choose D_s as the legal status of the Caspian Sea. Only the Plurality Rule is an exception, and then only in that it also recommends *C* in addition to D_s as a possible legal status.

We conclude that if one alternative must be selected, the choice of D_s is most likely to be consistent with the principles of social choice. However, we are not sure that this alternative is sustainable, because one state (Iran) ranks it last. Alternative *C* is worse, however, in the sense that two states (Turkmenistan and Azerbaijan) rank it as the least preferable resolution of the status of the Caspian Sea.

2.3 Fallback Bargaining

Fallback Bargaining (FB), introduced by Brams and Kilgour (2001), is an approach to bargaining that produces a prediction about the bargaining outcome. Bargainers are seen as beginning by insisting on their most preferred alternatives, then falling back, in lockstep, to less preferred alternatives until there is an alternative with sufficient support (i.e. majority or supermajority support, or unanimity, as appropriate). The outcome of Fallback Bargaining is a subset of alternatives called the Compromise Set (CS), which may be compared to the product of a social choice rule.

Fallback Bargaining has many variants. Brams and Kilgour show that Unanimity Fallback Bargaining (UFB) leads to the alternative(s) receiving unanimous support at the highest possible level. In Unanimity Fallback Bargaining, the Compromise Set consists of exactly those alternatives that maximize the minimum satisfaction among all bargainers. In addition to Unanimity Fallback Bargaining, other variants are used below to predict the outcome of the Caspian Sea negotiations. If a decision rule other than unanimity is adopted, the outcome of Fallback Bargaining may be different from the UFB outcome. If preferences are strict, any Fallback Bargaining outcome is Pareto-optimal, but need not be unique; the UFB outcome is at least middling in everybody's ranking. Fallback Bargaining does not necessarily select a Condorcet alternative, or even the first choice of a majority of bargainers. However, it maximizes the satisfaction of the most dissatisfied bargainer.

2.3.1 Unanimity Fallback Bargaining Procedure

In Fallback Bargaining, the *depth of agreement* (d^*) is the level of support at which a Compromise Set is acceptable. As shown below, the Unanimity Fallback Bargaining procedure recommends *DC* and D_m as the legal status of the Caspian Sea, and the *depth of agreement* is 4.

$$\begin{array}{l} \text{Azerbaijan} \\ \text{Iran} \\ \text{Kazakhstan} \\ \text{Russia} \\ \text{Turkmenistan} \end{array} \left(\begin{array}{cccc:c} D_s & D_m & DC & D_e & C \\ C & D_e & D_m & DC & D_s \\ D_s & D_m & DC & C & D_e \\ C & DC & D_s & D_m & D_e \\ D_e & D_s & D_m & DC & C \end{array} \right) \Rightarrow CS = \{DC, D_m\}$$

2.3.2 q-Approval Fallback Bargaining

For any fixed number of bargainers *q*, Brams and Kilgour (2001) define *q*-Approval Fallback Bargaining as the rule that picks the alternative(s) receiving the support of *q* parties at the highest possible level. Majoritarian Compromise and Unanimity Fallback Bargaining are particular cases of *q*-Approval Fallback Bargaining when *q* is equal to majority and unanimity, respectively. Moreover, *q*-Approval Fallback Bargaining coincides with the Plurality Rule when *q* = 1.

Any alternative accepted by at least *q* bargainers is added to the Compromise Set CS^q. If the legal status of the Caspian Sea could be determined by a majority (at least 3) bargainers, the Compromise Set would be

$$
\begin{array}{l}
\text{Azerbaijan} \\
\text{Iran} \\
\text{Kazakhstan} \\
\text{Russia} \\
\text{Turkmenistan}
\end{array}
\quad
\left(
\begin{array}{ccc|cc}
D_s & D_m & DC & D_e & C \\
C & D_e & D_m & DC & D_s \\
D_s & D_m & DC & C & D_e \\
C & DC & D_s & D_m & D_e \\
D_e & D_s & D_m & DC & C
\end{array}
\right) \Rightarrow CS^4 = \left\{ D_s, D_m \right\}
$$

Simple Majority Fallback Bargaining arises from setting $q = \left\lfloor {(n+1)}/{2} \right\rfloor = \left\lfloor 5+1/2 \right\rfloor = 3$, which in this example produces

$$
\begin{array}{l}
\text{Azerbaijan} \\
\text{Iran} \\
\text{Kazakhstan} \\
\text{Russia} \\
\text{Turkmenistan}
\end{array}
\quad
\left(
\begin{array}{cc|ccc}
D_s & D_m & DC & D_e & C \\
C & D_e & D_m & DC & D_s \\
D_s & D_m & DC & C & D_e \\
C & DC & D_s & D_m & D_e \\
D_e & D_s & D_m & DC & C
\end{array}
\right) \Rightarrow CS^3 = \left\{ D_s \right\}
$$

If q = 3, the Depth of Agreement (d_3^*) is 2. The 3-Approval Compromise Set (CS^3**)** comprises exactly the outcome that maximizes the minimum satisfaction of the three most satisfied bargainers, which in this case are the three newly-independent countries, consisting of Turkmenistan, Azerbaijan, and Kazakhstan.

2.3.3 Fallback Bargaining with Impasse

Brams and Kilgour (2001) also supposed that additional data might be available whereby bargainers could make use of an "impasse" in their rankings, indicating an outcome below which they would prefer no agreement. The impasse itself could then become the fallback outcome, foreclosing any agreement. Each bargainer's impasse (walk-away) level is indicated by "*I*" in his or her preference ranking. We developed these additional data as follows:

- Azerbaijan and Kazakhstan have proclaimed their disagreement with the Condominium approach and equal division of the Caspian Sea. Therefore, these two countries might prefer no agreement to alternatives C and D_e .
- Iran has insisted that the system of division should yield Iran a share of not less than 20% of the sea and that the division of the sea surface should exactly match the

division of the seabed. Therefore, Iran might prefer no agreement to alternatives D_m , DC and D_s .

Since Russia and Turkmenistan want an agreement, we insert *I* at the end of their rankings. The following shows the bargainers' preferences among the alternatives when they are allowed to indicate "impasse" in their rankings:

$$\begin{array}{l} \text{Iran} \\ \text{Russia} \\ \text{Turkmenistan} \\ \text{Azerbaijan} \\ \text{Kazakhstan} \end{array} \quad \begin{pmatrix} C & D_e & I & D_m & DC & D_s \\ C & DC & D_s & D_m & D_e & I \\ D_e & D_s & D_m & DC & C & I \\ D_s & D_m & DC & I & D_e & C \\ D_s & D_m & DC & I & C & D_e \end{pmatrix} \Rightarrow CSI = \{I\}$$

This calculation means that no alternative maximizes the minimum satisfaction of all bargainers in the case of an impasse. This result explains why the parties have not yet reached a unanimous agreement regarding the legal status of the Caspian Sea. But 4-Approval Fallback bargaining with impasse yields a solution: alternative D_s maximizes the minimum satisfaction of all bargainers, with the exception of Iran.

$$\begin{array}{l} \text{Iran} \\ \text{Russia} \\ \text{Turkmenistan} \\ \text{Azerbaijan} \\ \text{Kazakhstan} \end{array} \quad \left(\begin{array}{ccc|ccc} C & D_e & I & D_m & DC & D_s \\ \hdashline C & DC & D_s & D_m & D_e & I \\ D_e & D_s & D_m & DC & C & I \\ D_s & D_m & DC & I & D_e & C \\ D_s & D_m & DC & I & C & D_e \end{array}\right) \Rightarrow CS^4 I = \{D_s\}$$

The depth of this agreement is 3.

2.3.4 Conclusions

Several variants of the Fallback Bargaining method are applied in this section to predict the bargaining outcome of the Caspian Sea negotiations. Different variants in some cases lead to different solutions. However, the predictions of the Unanimity Fallback Bargaining Procedure must be given special weight in light of the fact that the five presidents of the Caspian Sea states recently issued a joint declaration (at the end of the Tehran meeting in October 2007) in which they agreed that the legal regime of the Caspian Sea should be determined unanimously. ("The sides believe that the Caspian Sea legal regime convention is authorized to determine the Caspian Sea legal regime, which can only be approved through the littoral states' consensus.") The Unanimity Fallback Bargaining Procedure recommends two compromise alternatives: DC and D_m. Although for both of these alternatives a unanimous agreement among all of the bargainers occurs at the fourth level (depth) of agreement, D_m has a higher Borda Score than DC (11 versus 9). Hence, D_m might be an appropriate resolution for recommendation. At least we can say that if the division schema based on the International Law of the Seas is adopted as the legal status of the Caspian Sea, the intensity of conflicts and controversial disputes would probably be minimized. On the other hand, it is noteworthy that the Fallback Bargaining with Impasse procedure predicts that no agreement will be reached at all.

2.4 Bankruptcy Procedure for Resource Allocation

2.4.1 Introduction

> *"Consider a situation in which a man dies and his estate is insufficient to meet his debts. The bankruptcy problem deals with the following question: how to divide the estate among all creditors. The natural approach to this problem would be to look for allocation rules that satisfy some desired properties."* (Dagan and Volji, 1993)

At present, the Caspian Sea's claimants (the five states) seem to be following a cooperative rather than a competitive approach. Now the problem is to determine a fair resource allocation plan. The total value of the oil and natural gas located in the seabed of the Caspian Sea is not sufficient to provide Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan with all of the revenue they claim.

Bankruptcy procedures, which are related to cooperative game theory concepts, are suitable for fair division problems in which the total amount of the asset is not sufficient to cover all creditors' claims. We will use some bankruptcy procedures to determine each state's fair share of the wealth generated from the Caspian Sea region.

2.4.2 The Value of Creditors' Claims

First, we calculate the value of the oil and natural gas claimed by each regional state. The information contained in Table 2.4 is associated with Figure 1.3.

Table 2.4: Caspian Sea region's oil and natural gas reserves based on the International Law of the Seas (Oil is in billions of barrels / Gas is in trillions of cubic feet)

Regional States	Proven oil (bbl)	Possible oil (bbl)	Total oil (bbl)	Proven Gas (tcf)	Possible Gas (tcf)	Total Gas (tcf)
Azerbaijan	7	32	39	48	35	83
Iran [b]	0.1	15	15.1	0	11	11
Kazakhstan	9	92	101	65	88	153
Russia [b]	1	7	8	N/A	N/A	65
Turkmenistan	0.5	38	38.5	101	159	260

b Only regions near the Caspian Sea are included.

Source: BP. *BP Statistical Review of World Energy 2004.*

We suppose that the natural gas price in the region is approximately US$6 per thousand cubic feet since the price of natural gas supplied to the Ukraine by Gazprom (Russia's national gas company) in January 2006 is equivalent to US$230 per thousand cubic meters and a cubic meter is approximately 35.3 cubic feet. In addition, the average price of natural gas imported by the USA in March 2006 was $7.01 per thousand cubic feet [U.S. Energy Information Administration, 2006].

Table 2.5: The value of oil and natural gas reserves based on the International Law of the Seas Natural gas prices are in US$ per thousand cubic feet.

Regional States	Total Oil (bbl)	Average Oil Price ($/bbl)	Oil value (billion$)	Total Gas (tcf)	Natural Gas Price ($/tcf)	Gas value (billion$)	Total value (billion$)
Azerbaijan	39	50	1950	83	6	498	2448
Iran [b]	15.1	50	755	11	6	66	821
Kazakhstan	101	50	5050	153	6	918	5968
Russia [b]	8	50	400	65	6	390	790
Turkmenistan	38.5	50	1925	260	6	1560	3485
Sum	201.6	50	10080	572	6	3432	13512

The results of Table 2.5 would be valid even if the legal status of the Caspian Sea were considered to be *condominium on surface and division of the seabed (DC)* because only the oil and natural gas located within each state's seabed sector (based on the International Law of the Seas) are considered as valuable assets.

If the legal status of the Caspian Sea were considered to be totally *condominium*, all five states would possess an equal share of the oil and natural gas in the seabed. Therefore, 40.32 billion barrels of oil and 114.4 trillion cubic feet of natural gas would be allocated to each regional state. Table 2.6 shows these values for each state.

Table 2.6: The value of oil and natural gas reserves based on the *condominium* regime

Regional States	Total Oil (bbl)	Average Oil Price ($/bbl)	Oil Value (billion$)	Total Gas (tcf)	Natural Gas Price ($/tcf)	Gas Value (billion$)	Total Value (billion$)
Azerbaijan	40.32	50	2016	114.4	6	686.4	2702
Iran	40.32	50	2016	114.4	6	686.4	2702
Kazakhstan	40.32	50	2016	114.4	6	686.4	2702
Russia	40.32	50	2016	114.4	6	686.4	2702
Turkmenistan	40.32	50	2016	114.4	6	686.4	2702
Sum	201.6	50	10080	572	6	3432	13512

For example, the division of the Caspian Sea based on Soviet maps (D_s) is most preferable for Azerbaijan since it would receive 22.4 percent of the Sea, versus only 21 percent based on the International Law of the Seas (D_m**).** We do not have access to the precise amount of the oil and natural gas that is located in Azerbaijan's territory based on the division referring to the Soviet maps, so we extrapolated those data based on the information in Tables 2.5 and 2.7, and Figure 2.3.

Table 2.7: Percentage shares allocated to each country based on the type of division

Country	Based on International Law of the Seas (D_m)	Equal division (D_e)	Referring to Soviet maps (D_s)
Azerbaijan	21%	20%	22.4%
Iran	13.6	20	11
Kazakhstan	28.4	20	28.4
Russia	19	20	19
Turkmenistan	18	20	19.2

The amount of oil in Azerbaijan's territory according to the division of the Caspian Sea based on Soviet maps is estimated to be 41.19 billion barrels. This approximation is founded on the assumption that the extra 1.4 percent of the Sea allocated to Azerbaijan based on D_s compared with D_m is transferred from Iran and is calculated as:

$$39+(22.4-21)\frac{39+15.1}{21+13.6}=41.19 \text{ billion barrels.}$$

Likewise, the approximate amount of natural gas located in Azerbaijan's territory based on D_s is 86.8 trillion cubic feet.

$$83+(22.4-21)\frac{83+11}{21+13.6}=86.8 \text{ Trillions of cubic feet}$$

Equal division of the Caspian Sea (D_e) is the best alternative for Turkmenistan because this arrangement would yield Turkmenistan 2.0 percent more than the International Law of the Seas (D_m). We assume that this amount would be taken in equal parts from Azerbaijan and Kazakhstan. Turkmenistan's approximate resource levels under D_e would be 43.8 billion barrels of oil and 274.72 trillion cubic feet of natural gas.

We mentioned the preferences of the five littoral states in the previous sections. To apply bankruptcy procedures, we suppose that the claim of each of these states is equal to the greatest amount that it would receive under any alternative.

Table 2.8: The amount of oil and natural gas claimed by regional states

Regional States	The best alternative	Total claimed oil (bbl)	Total claimed gas (tcf)
Azerbaijan	D_s	41.19	86.8
Iran	C	40.32	114.4
Kazakhstan	D_s	101	153
Russia	C	40.32	114.4
Turkmenistan	D_e	43.8	274.72

Table 2.9: The values of oil and natural gas claimed by regional states

Regional States	Total Oil (bbl)	Average Oil Price ($/bbl)	Oil Value (billion$)	Total Gas (tcf)	Natural Gas Price ($/tcf)	Gas Value (billion$)	**Total Value (billion$)**
Azerbaijan	41.19	50	2059.5	86.8	6	520.8	**2580**
Iran	40.32	50	2016	114.4	6	686.4	**2702**
Kazakhstan	101	50	5050	153	6	918	**5968**
Russia	40.32	50	2016	114.4	6	686.4	**2702**
Turkmenistan	43.8	50	2190	274.72	6	1648.32	**3838**
Sum	266.63	50	13331.5	743.32	6	4459.9	**17791**

The total value of oil and natural gas claimed by the five littoral states is US$17791 billion, which is approximately 32% more than the total value of proven and possible oil and gas located in the seabed of the Caspian Sea ($13512 billion).

2.4.3 Basic Concepts and Definitions

A ***bankruptcy problem*** is a pair **(*E, c*)** where $\mathbf{c} = (c_1, c_2, ..., c_n) \geq 0$, $0 \leq E \leq \sum_{i=1}^{n} c_i$. E represents the total value of the estate, and ***c*** is the vector of the creditors' claims. The sum of these claims is denoted by C ($\sum_{i=1}^{n} c_i = C$) and the set of all creditors by N. An ***allocation*** is an n-tuple $x = (x_1, x_2, ..., x_n) \in R^n$ with $\sum_{i=1}^{n} x_i = E$ and $0 \leq x_i \leq c_i$, $i = 1, ..., n$.

Denoting A: Azerbaijan; I: Iran; K: Kazakhstan; R: Russia; and T: Turkmenistan, we write c, the vector of creditors' claims, as follows:

$c = (c_A, c_I, c_K, c_R, c_T) = (2580, 2702, 5968, 2702, 3838)$

Then $0 < E = 13512 < C = 17791$.

2.4.4 Bankruptcy Rules for Resource Allocation

Now, we allocate the value of the oil and natural gas in the Caspian Sea to the claimant states. Note that the objective is different from Sections 2.2 and 2.3, where we sought a resolution: we now assume that an allocation can be implemented by transferring money from state to state in accordance with the allocation. An ***allocation rule*** is a function that assigns a unique allocation to each bankruptcy problem.

(a) The ***proportional rule*** is defined as follows:

$g^{\mathrm{Pr}}(E, c) = \lambda c$, where $\lambda C = E$.

The proportional rule allocates awards in proportion to the claims. The proportionality principle was favored by the philosophers of ancient Greece; Aristotle even considered it synonymous with justice. The proportional rule is widely used nowadays.

$$\lambda\ C = E \Rightarrow \lambda = \frac{E}{C} = \frac{13512}{17791} = 0.76$$

$$g^{\Pr}(E,c) = \lambda c\ = (1960, 2052, 4533, 2052, 2915)$$

The ***proportional rule*** proposes an allocation of $1960, $2052, $4533, $2052, and $2915 billion for Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan, respectively.

(b) The ***constrained equal award (CEA) rule*** is defined as follows:

$g^{CEA}(E,c) = x$ where $x_i = \min(\lambda, c_i)$ and λ solves the equation $\sum_{i \in N} \min(\lambda, c_i) = E$.

This rule assigns the same sum to all creditors, except that no creditor receives more than his or her claim. In other words, it divides the estate equally among the creditors, constrained by their claims.

Note 1 - For each well-defined bankruptcy problem, the set of its allocations is non-empty.

Note 2 - The equation has a unique solution when C > E. If C = E, any solution λ is greater than or equal to the maximum claim and, therefore, $x_i = c_i$ for all *i*.

Among the Caspian Sea's creditors, Azerbaijan has the smallest claim, $c_A = 2580$. So, we equally allocate $2580 billion to all of the claimants in the first stage. In this case, Azerbaijan would be satisfied by this stage.

5*2580 = $12900 billion is assigned in the first stage of allocation to all of the creditors.

13512 - 12900 = $612 billion = remainder for other allocations.

After Azerbaijan, Iran and Russia have the least amount of claims and request only 122 extra billion Dollars to be satisfied. (2702 – 2580 = 122)

In the second stage of allocation, we equally add this 122 billion dollars to the rest of the claimants.

4*122 = $488 billion is assigned in the second stage of allocation. Hence, Azerbaijan, Iran and Russia have been satisfied so far.

612 – 488 = $124 billion = reminder for the third allocation

Although there is 124 billion dollars available for the next stage of allocation, it is not possible to satisfy another claimant since Turkmenistan requests 1136 extra billion dollars (3838 – 2702) to be satisfied and there is not 2*1136 extra billion dollars to be divided equally among two claimants. Hence, we can add half of the remaining money (62 billion$) to both Turkmenistan and Kazakhstan's shares. This means that $\lambda = 2702 + 62 = 2764$

$g^{CEA}(E,c) = x$ = (2580, 2702, 2764, 2702, 2764)

The process of resource allocation based on the constrained equal award (CEA) rule is illustrated in Figure 2.4. As the graph shows, Azerbaijan, Iran and Russia can achieve the amount that they claim based on this rule, whereas Kazakhstan and Turkmenistan do not.

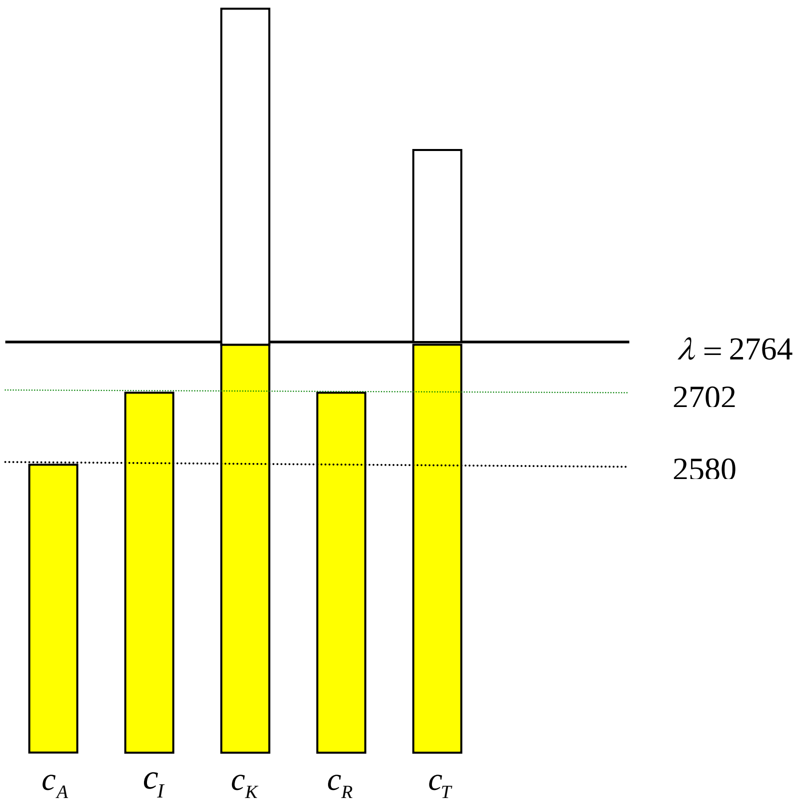

Figure 2.4 - The process of resource allocation based on the constrained equal award (CEA) rule

Another rule, defined only for two-creditor problems, is the ***contested garment principle,*** which is defined as follows:

$$g^{CG}(E,(c_1,c_2)) = \left(\frac{E + c_1^E - c_2^E}{2}, \frac{E + c_2^E - c_1^E}{2}\right). \text{ where } c_i^E = \min\{c_i, E\}.$$

As a legal concept, c_i^E may be interpreted as that part of E claimed by creditor ***i*.** He cannot claim more than is there and, thus c_i^E can be interpreted as the relevant claim given E. This rule cannot be applied for the Case of Caspian See because there are more than two creditors in Caspian See negotiations. In order to define the next rule, we need the following definition:

For each bankruptcy problem *(E, c)* and creditor ***i*,** define $\nu_i^{(E,c)} = \max\left\{0; E - \sum_{j\neq i} c_j\right\}$.

The symbol $\nu_i^{(E,c)}$ is the amount of money conceded to creditor ***i*** by all other creditors.

Whenever there is no danger of confusion we write simply ν_i instead of $\nu_i^{(E,c)}$. It can be shown that if x is an allocation, then $\nu_i \leq x_i$, which means that ν_i is the minimum amount of money that may be assigned to ***i*** by any allocation rule.

(c) The ***adjusted proportional*** *(AP)* ***rule*** is defined as follows: $g^{AP}(E,c) = x$ where

$x_i = \nu_i + (c_i^E - \nu_i)(\sum_{j\in N}(c_j^E - \nu_j))^{-1}(E - \sum_{j\in N}\nu_j)$, if $C > E > 0$

$c_i^E = \min\{c_i, E\} = \min\{c_i, 13512\} = c_i$ and $\nu_i^{(E,c)} = \max\left\{0; E - \sum_{j\neq i} c_j\right\}$

The g^{AP} can be interpreted as allocating E in two stages. In the first stage, each creditor i obtains what the others concede, i.e. ν_i , leaving $E - \sum_{i\in N}\nu_i$ for the next stage. In the second stage, g^{AP} divides the remainder in proportion to the outstanding claims.

For the case of Caspian Sea, $c_i^E = c_i$ for all of the claimants since

$c_i^E = \min\{c_i, E\} = \min\{c_i, 13512\} = c_i$ for all i in N, and $\nu_i^{(E,c)} = \max\left\{0; E - \sum_{j\neq i} c_j\right\}$.

$$\Rightarrow \nu_A^{(13512,c)} = \max\{0; 13512 - (c_I + c_K + c_R + c_T)\} = \max\{0; (13512 - 15211)\} = 0$$
$$\Rightarrow \nu_I^{(13512,c)} = \max\{0; 13512 - (c_A + c_K + c_R + c_T)\} = \max\{0; (13512 - 15089)\} = 0$$
$$\Rightarrow \nu_K^{(13512,c)} = \max\{0; 13512 - (c_A + c_I + c_R + c_T)\} = \max\{0; (13512 - 11823)\} = 1689$$
$$\Rightarrow \nu_R^{(13512,c)} = \max\{0; 13512 - (c_A + c_I + c_K + c_T)\} = \max\{0; (13512 - 15089)\} = 0$$
$$\Rightarrow \nu_T^{(13512,c)} = \max\{0; 13512 - (c_A + c_I + c_K + c_R)\} = \max\{0; (13512 - 13953)\} = 0$$
$$x_i = \nu_i + (c_i^E - \nu_i)(\sum_{j\in N}(c_j^E - \nu_j))^{-1}(E - \sum_{j\in N}\nu_j)$$

$$(\sum_{j\in N}(c_j^E - v_j))^{-1} = (2580 + 2702 + (5968 - 1689) + 2702 + 3838)^{-1} = \frac{1}{16101} = 6.2107 * 10^{-5}$$

$$(E - \sum_{j\in N} v_j) = 13512 - (0 + 0 + 1689 + 0 + 0) = 11823$$

$$(\sum_{j\in N}(c_j^E - v_j))^{-1}(E - \sum_{j\in N} v_j) = 6.2107 * 10^{-5} * 11823 = 0.7343$$

$$x_i = v_i + (c_i^E - v_i)(\sum_{j\in N}(c_j^E - v_j))^{-1}(E - \sum_{j\in N} v_j)$$

$$\Rightarrow x_A = v_A + (c_A - v_A)(0.7343) = 0 + (2580 - 0)(0.7343) = 1895$$

$$\Rightarrow x_I = v_I + (c_I - v_I)(0.7343) = 0 + (2702 - 0)(0.7343) = 1984$$

$$\Rightarrow x_K = v_K + (c_K - v_K)(0.7343) = 1689 + (5968 - 1689)(0.7343) = 4831$$

$$\Rightarrow x_R = v_R + (c_R - v_R)(0.7343) = 0 + (2702 - 0)(0.7343) = 1984$$

$$\Rightarrow x_T = v_T + (c_T - v_T)(0.7343) = 0 + (3838 - 0)(0.7343) = 2818$$

$g^{AP}(E, c) = x = (1895, 1984, 4831, 1984, 2818)$.

2.4.5 Comparison of Bankruptcy Allocations

The allocations resulting from the application of the three bankruptcy procedures to the oil and gas resources of the Caspian Sea are summarized in Table 2.10.

Table 2.10: The results of assignment based on different rules of resource allocations Amounts are in billions of US$.

Regional States	***(a)Proportional rule***	***(b)Constrained equal award (CEA) rule***	***(c)Adjusted proportional (AP) rule***
Azerbaijan	1960	2580	1895
Iran	2052	2702	1984
Kazakhstan	4533	2764	4831
Russia	2052	2702	1984
Turkmenistan	2915	2764	2818
Sum	13512	13512	13512

We now discuss how resource allocation rules could be implemented. For example, suppose that D_m (division based on the International Law of the Seas) has been determined to be an appropriate or convenient regime, but that the claimants agree to implement the *constrained equal award rule*. Based on D_m, each state is to extract the oil and natural gas located in its exclusive territory; it then receives or pays some compensation. Table 2.10 illustrates that Azerbaijan would receive $2580 billion according to the *constrained equal award rule*, although the value of the oil and natural gas reserves located in the Azerbaijan sector (based on D_m) is only $2448 billion (see Table 2.5). Azerbaijan would, therefore, receive an additional $132 billion in compensation. On the other hand, other states would be obligated to pay into the compensation pool. For instance, Turkmenistan would pay $721 billion as compensation because the oil and natural gas reserves located in the Turkmenistan sector (based on D_m) are worth $3485 billion, but only $2764 billion is to be assigned to Turkmenistan according to the *constrained equal award rule*.

Table 2.10 shows that applying different rules leads to different allocations. Hence, the preferences of the five states among the resource allocation rules are not identical, as Table 2.11 illustrates.

Table 2.11: The preferences of the regional states
among the different rules of resource allocations

Regional States	The most desirable rule	The second most desirable rule	The least desirable rule
Azerbaijan	b	a	c
Iran	b	a	c
Kazakhstan	c	a	b
Russia	b	a	c
Turkmenistan	a	c	b

We now apply social choice rules and Fallback Bargaining procedures to select the most appropriate allocation rule. As indicated in Table 2.12, all of the social choice rules discussed here select rule (b), the ***constrained equal award*** rule, although the Borda SCR also chooses

(a) in addition to (b). Rule (a), the ***proportional*** rule, is also selected by the Unanimity Fallback Bargaining procedure.

Table 2.12: The selected rule based on social choice and Fallback Bargaining procedures

Social choice and Fallback Bargaining procedures	**The selected rule**
Condorcet winner – Plurality – MC – MVR – CPM	b
Borda Score	a – b
Unanimity Fallback Bargaining Procedure	a

2.4.6 Bankruptcy Allocations: Conclusions

The *constrained equal award rule* is socially optimal according to all of the applied social choice rules. However, resource allocation based on the *proportional rule* maximizes the minimum satisfaction across all five states; the Unanimity Fallback Bargaining procedure selects this rule. In other words, the *proportional rule* would probably be easier to implement since none of the states strongly objects to it.

2.5 The Graph Model for Conflict Resolution

The Graph Model for Conflict Resolution (Fang, Hipel, and Kilgour, 1993) is a methodology to model and analyse DMs' interactions in a conflict in order to find states stable for all of the decision makers, which are interpreted as feasible resolutions of the conflict. The Graph Model, which constitutes an extension of *conflict analysis* (Fraser and Hipel, 1984), which in turn is an improvement over *metagame theory* (Howard, 1971), utilizes concepts and definitions from graph theory, set theory, and game theory.

In a graph model, a state is a potential outcome of the conflict, or scenario. Each DM's possible moves from one state to another are illustrated using a directed graph in which nodes represent states and arcs indicate the state-to-state transitions controlled by the DM. A graph model for a conflict consists of a collection of directed graphs. The Graph Model can handle both transitive and intransitive preferences. However, in most real life conflicts DMs' preferences can be assumed to be transitive and thus expressed as a ranking (ordering) of the states from most to least preferred, where ties are allowed.

The systematic procedure for applying the Graph Model follows the two main stages modeling and analysis. In the modeling stage, the problem is structured by determining the DMs, the states, the possible state transitions controlled by each DM, and each DM's relative preferences over the states. Next, in the analysis stage, the stability of each state from each DM's viewpoint is determined. The objective is to find stable states.

The essential parts of a Graph Model in option form are the DMs and the options or courses of action available to each DM. In general, a DM may exercise any combination of the options he or she controls. When every DM has selected a set of options, a state is defined. Of course, there may be restrictions on the option choices or changes of options available to a DM. When these are specified, the feasible states, which constitute the actual set of realizable states in the model, and allowable transitions, can be easily determined.

Often there are logical reasons why a particular combination of options does not represent a feasible state. If so, the combination is removed since it cannot form a feasible state. The followings are the most common types of infeasibility:

- Among some options, at least one must be taken.
- Among some options, at most one can be taken (mutually exclusive). For instance, either option A or option B can be chosen, possibly neither, but not both.
- An option's availability depends on the selection of another option. For example, option A can be selected only if option B is chosen.
- An option must be taken when another option is selected. For example, A must be taken when B is taken.

The state-to-state transitions controlled by a DM are exactly those implied by a unilateral change of the DM's option selection. These steps produce the usual set of directed graphs, and the graph model is completed by each DM's relative preferences among the feasible states. Since each DM's graph has the same set of nodes; it is often useful to show all DMs' graphs on the same diagram by simply integrating them and labelling each arc to indicate the DM who controls it. Such a graph is called the integrated graph of the model.

In a Graph Model, the set of all states that DM *i* can unilaterally reach from state *s* in one step is the *reachable list (R).* A unilateral improvement (UI) from a particular state for a specific DM is a preferred state (for that DM) to which he or she can unilaterally move in one step. It follows that R can be partitioned into two subsets: the set of *unilateral improvements* from state s for DM i; and the set of *unilateral disimprovements* from state s for DM i.

The associated decision support system GMCR II (Fang *et al.* 2003 a, b) conveniently implements the graph model for conflict resolution. It incorporates the option form for conflict modeling, and determines the stability of every state for each DM under a broad range of stability types. GMCR II is generally able to produce a variety of equilibrium information which enhances the analyst's understanding of the conflict and results in useful advice to specific DMs on whether possible outcomes are strategically stable.

The stability of states for DMs is defined by various solution concepts, or stability definitions. Nash stability (Nash, 1950, 1951) reflects a DM who thinks only one step ahead. In general metarationality (GMR) (Howard, 1971) and sequential stability (SEQ) (Fraser and Hipel, 1984), a DM considers exactly two steps ahead; whereas in symmetric metarationality (SMR) (Howard, 1971), the DM takes into account three steps by assessing available escapes from any sanctions that may be imposed by the opponents. A disimprovement is a move to a less preferred state in order to reach a more preferred state eventually, or to block unilateral improvements of other DMs. In Nash and sequential stability, disimprovements are never permitted, while in general and symmetric metarationality disimprovements by the opponents for the purpose of sanctioning are allowed. The Graph Model also provides other, more sophisticated stability definitions, which are also implemented in GMCR II.

Since different solution concepts may be appropriate for different DMs, states that are stable under many solution concepts are usually preferred. Thus, it is important to consider more than one kind of solution concept for each DM to ensure a robust prediction of the conflict resolution.

2.6 Limitations of the Existing Models

We now describe why the models explained in this Chapter are not entirely satisfactory when reaching agreement is the main objective of DMs in asymmetric multilateral negotiations.

Social choice rules are not comprehensive enough to describe and analyze multilateral negotiations such as Caspian Sea negotiations. Social choice theory deals with the principles of preference aggregation in the sense that individual preference is to be reflected equitably in group preference. It is mostly applicable to democratic decision-making by committees or electorates while, in real-world multilateral negotiations, DMs possess different levels of power or legitimacy. In addition, DMs' first concerns are their own preferences.

Like social choice theory, fallback bargaining procedures have some limitations. Fallback bargaining methods may describe two-person negotiations well, but are not easily generalized to multilateral negotiations. Moreover, fallback bargaining assigns equal weight to all decision makers.

Bankruptcy solutions apply to resource allocation problems but they are natural only in a Transferable Utility context, since they determine how to allocate a fixed amount of money, usually. In a Transferable Utility (TU) game, players can freely transfer utility to other players. Approaches suitable for TU games cannot be applied when there are issues for which utility is not transferable.

Solution concepts of the Graph Model for Conflict Resolution are not applicable in multilateral negotiations when reaching an agreement is a main objective of DMs. In the Graph Model for conflict resolution, options are actions that might be carried out by the DMs, while in multilateral negotiations, like the Caspian Sea model, the DMs do not carry out actions but support, or not, a specific alternative as the outcome of the negotiation. In the Graph model, the basic objective is to identify stability rather than to follow a possible evolution. In the Graph model, reaching agreement is not the essential objective.

2.7 Summary

This Chapter introduces several existing models for predicting the outcome of a negotiation. Social Choice Rules, Fallback Bargaining Procedures, and Bankruptcy Solutions are applied to the current negotiations over the legal status of the Caspian Sea to predict or recommend the most appropriate resolution among the proposed alternatives. In addition, the Graph Model for Conflict Resolution and its associated DSS GMCR II are briefly discussed, but not applied. Then, reasons why the existing models are not appropriate when reaching an agreement is the main objective of DMs in asymmetric multilateral negotiations are put forward. To resolve the limitations of the existing models, new definitions and methodology are proposed in the next Chapter.

Chapter 3

Proposed Methodology for Modeling Multilateral Negotiations

The negotiation problems modeled in this chapter are distinctive because the set of possible agreements is discrete and specified in advance. Each decision maker has two concerns: first, achieving an alternative that is as preferable as possible to himself or herself; second, building support for this alternative among the other decision makers. New definitions and methodologies are proposed in this chapter to model and analyze multilateral negotiations. The main objective of this research is to formulate methodologies to predict the most likely outcomes of a particular form of multilateral negotiation, based on the capabilities of the decision makers and their preferences over the available alternatives. The methodology proposed in this chapter analyzes multilateral negotiations with the following general characteristics:

- Decision makers in the negotiation look for a feasible resolution, in other words, a stable or enduring agreement. Of course, each negotiator tries to attain the most preferable agreement for himself or herself.
- If an agreement is reached, it must be an alternative from a prespecified list, which all decision makers must accept.
- Decision makers can possess different levels of capability (power or legitimacy) in support of an agreement, so the negotiation is not necessarily symmetric.
- The analysis makes use of only the preference order of each decision maker over the

proposed alternatives, and does not require cardinal measures of preference.

3.1 Definitions

We now propose new definitions which will be applied in the proposed methodology, to identify the likely agreements and specify their likelihoods. Suppose that $N = \{1, 2, 3, ..., n\}$ is the set of all decision makers (DMs) in the negotiation, and $A = \{a_1, a_2, ..., a_q\}$ is the set of all alternative agreements. We assume $n \geq 2$ and $q \geq 2$.

Definition1: DMs' Preference Rankings over Agreements

For $i \in N$, $\succsim_i$ is DM *i*'s weak preference relation on A. Thus, $a_k \succsim_i a_j$ means *i* prefers a_k to a_j or is indifferent between a_k and a_j. The relation $\succsim_i$ is assumed to be reflexive and complete. Strict preference for DM *i* is the relation $\succ_i$, defined on A by $a_k \succ_i a_j$ iff $a_k \succsim_i a_j$ and $\neg(a_j \succsim_i a_k)$, where $\neg$ means negation. For $i \in N$, $\sim_i$ is DM *i*'s indifference relation on A; $a_j \sim_i a_k$ iff $a_k \succsim_i a_j$ and $a_j \succsim_i a_k$. Preferences are usually transitive but not always, and the methodology developed herein can be used even when preferences are intransitive.

We define $P_i(a_j) = 1 + \left|\{a \in A : a \succ_i a_j\}\right|$ to indicate the preference of DM ***i*** over the alternative a_j. For example $P_2(B) = 1$ means that alternative B is the best alternative according to DM 2. Likewise, $P_3(A) = P_3(D) = 4$ indicates that DM 3 is indifferent between alternatives A and D and considers these alternatives as his or her fourth preference.

Definition 2: Acceptability

Each DM may be willing to accept only some of the proposed alternatives as the outcome of the negotiation. For each decision maker, acceptability is denoted by a positive integer. DM *i* will accept alternative a_j if and only if $P_i(a_j) \leq \mathrm{Acc_i}$.

Definition 3: Negotiation State

A negotiation state consists of an alternative and a non-empty subset of DMs who support that alternative as the outcome of the negotiation. Thus, (a_j, C) denotes a negotiation state where $a_j \in A$ and $C \subseteq N, C \neq \varnothing$. The set of all possible states is $S = A \times (2^N - \varnothing)$. Note that $|S| = q.(2^n - 1)$.

Definition 4: Feasibility

An agreement can be implemented if and only if the supporting coalition is strong enough. Hence, a negotiation state is feasible if the coalition defined by the state is strong enough to enforce the agreement defined by the state. To reflect that the power or legitimacy of different DMs may be different in real-world negotiations, we denote by w_i the weight of DM *i* in the negotiation. If the sum of coalition members' weights is at least equal to a threshold, T, then the negotiation state is feasible. Thus, the threshold is the least total weight of a coalition that is strong enough to enforce an agreement. Of course, this parameter must be determined before state feasibility can be assessed.

In summary, we assign a weight $w_i > 0$ to each $i \in N$, and, for each $a_j \in A$, a threshold $T(a_j) > 0$. A negotiation state (a_j, C) is feasible iff $\sum_{i \in C} w_i \geq T(a_j)$. The threshold may depend on the alternative when different alternatives require different levels of support to be feasible. If we simplify this further by assuming $T(a_1) = T(a_2) = T(a_3) = ... = T(a_q) = T$, then (a_j, C) is feasible iff $\sum_{i \in C} w_i \geq T$.

The specification of weights is a major issue when this methodology is applied. However, veto power can be consistent with this methodology. If we want to generalize the concept of feasibility in the negotiations in which some DMs possess veto power, then the threshold must be at least equal to sum of the veto players' weights.

Definition 5: Stability

A negotiation state from which there is no movement is called stable. Different types of movements are defined in the next section.

Definition 6: Fallback Distance

FD_i is a non-negative integer parameter describing DM *i*. In strategic disimprovements (see below), *i* is willing to accept a_k rather than a_j, even though $a_k \prec_i a_j$, if $P_i(a_k) - P_i(a_j) \le FD_i$. This parameter indicates the level that DM *i* is willing to retreat to a less preferred alternative to achieve an agreement.

Some members of the coalition associated with a negotiation state may prefer another state, feasible or infeasible. We now define several possible movements from one state to another.

3.2 Methodology

The proposed methodology is based on the analysis of stable states. To determine the stable states, we must describe the different possible movements. Members of the coalition of a negotiation state might move to another state for the following reasons:

- The members of the coalition find another alternative more preferable.
- One or more extra DMs join the coalition because they support the agreement that the coalition is enforcing.
- One or more members of a coalition may form another coalition (on their own or along with other DMs) to support another agreement.
- One or more members of a coalition may join another coalition supporting an agreement that is less preferable to the members who move. This strategic disimprovement must be a move from an infeasible state to a feasible one.

The third type of movement is called disloyalty, to capture the idea that some members of the initial coalition leave their "friends" in that coalition to form another coalition in order to support another agreement.

3.2.1 Mathematical definitions of movements

If there is a movement from (a_j, C) to (a_k, C'), we call (a_j, C) the initial or status quo state and (a_k, C') the subsequent state. Now, we propose mathematical definitions of these movements.

1) Preferential Improvement:

A preferential improvement is a change of state $(a_j, C) \rightarrow (a_k, C),$ where $a_k \succsim_i a_j$ for all $i \in C$ and for some $i \in C$, $a_k \succ_i a_j$. If there is another agreement preferred by all members of a given coalition, then there is a preferential improvement.

2) Agglomeration:

An agglomeration is a change of state $(a_j, C) \rightarrow (a_j, C'),$ where $C \subset C'$. In this case, a_j is acceptable for all $i \in (C' - C)$.

3) Disloyalty:

A disloyalty move is a change of state $(a_j, C) \rightarrow (a_k, D),$ when $j \neq k, C \neq D, C \bigcap D \neq \varnothing$, (a_k, D) is feasible, $a_k \succsim_i a_j$ for all $i \in D$, and, for some $i \in D$, $a_k \succ_i a_j$.

4) Strategic Disimprovement:

A strategic disimprovement is a change of stare $(a_j, C) \rightarrow (a_k, D),$ where $j \neq k, C \neq D, C \bigcap D \neq \varnothing$, (a_j, C) is infeasible, and (a_k, D) is feasible. Moreover, strategic disimprovement requires that:

(1) $\exists i \in C \bigcap D$ such that $a_k \prec_i a_j$

(2) $\forall i \in C \bigcap D; \quad P_i(a_k) - P_i(a_j) \leq FD_i$

(3) $\forall i \in D - C; \quad \mathrm{P_i(a_k)} \leq Acc_i$

Typically, a_k is not much worse than a_j for members of $C \bigcap D$, and is acceptable (reasonably good) for $D - C$. In this case, the members of $D - C$ are looking for strategic disimprovement at minimum cost. The greater FD_i , the more DM *i* is willing to retreat from a most preferred alternative in order to reach an agreement.

Figure 3.1 shows a flowchart for determining whether there is a Preferential Improvement from a given initial state like (a_j, C) to a subsequent state like (a_k, C') .

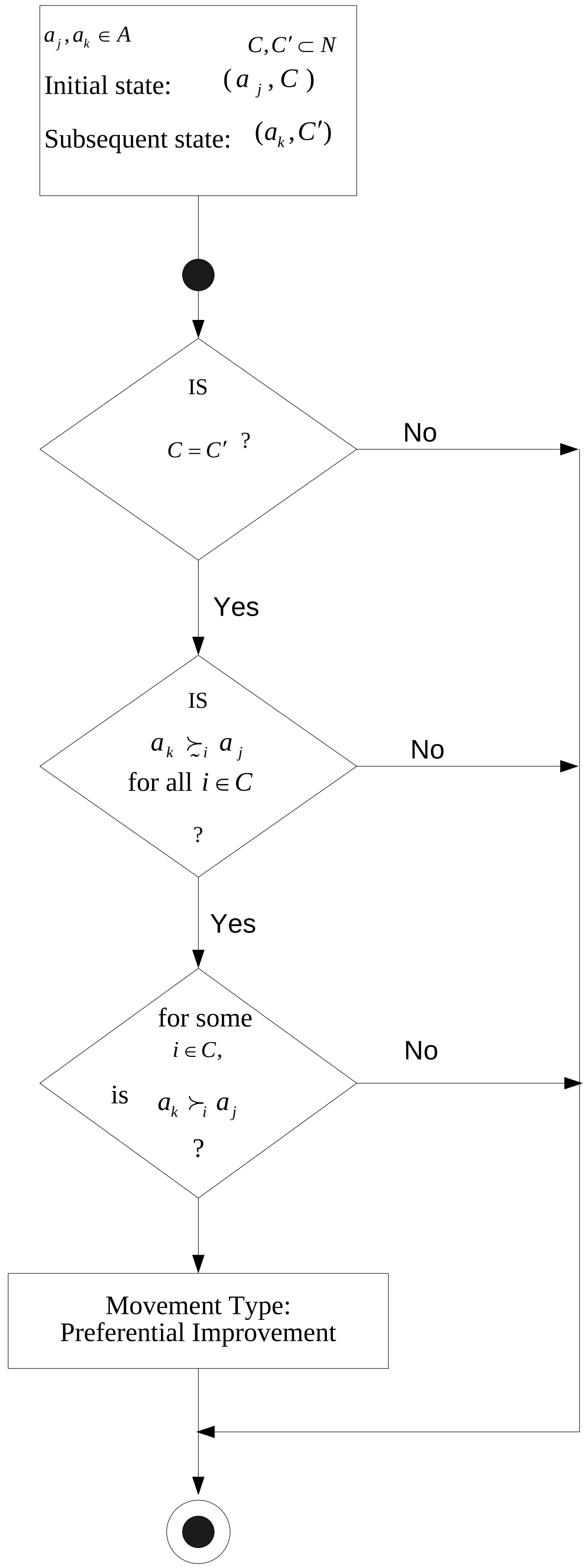

Figure 3.1 -Flowchart for determining whether there is a Preferential Improvement

Likewise, we can provide some flowcharts for other types of movement.

<u>Theorem:</u> It is impossible that two different types of movements occur simultaneously from a given initial state to a given subsequent state.

Proof: We want to show that all four defined movements are mutually exclusive.
Suppose that there is a disloyalty movement from an initial state (a_j, C) to a subsequent state (a_k, D). We show that no preferential improvement nor agglomeration movement nor strategic disimprovement can occur from state (a_j, C) to state (a_k, D).
If the movement $(a_j, C) \to (a_k, D)$ is a disloyalty movement, then $j \neq k, C \neq D, C \cap D \neq \varnothing$, (a_k, D) is feasible and $a_k \succsim_i a_j$ for all $i \in D$ and $a_k \succ_i a_j$ for some $i \in D$.

The movement $(a_j, C) \to (a_k, D)$ cannot be a preferential improvement because $C \neq D$ while a preferential improvement entails $C = D$. It also cannot be an agglomeration movement since $j \neq k$, whereas in an agglomeration movement $j = k$. The disloyalty movement $(a_j, C) \to (a_k, D)$ cannot be a strategic disimprovement because $a_k \succsim_i a_j$ for all $i \in D$, while a condition for a strategic disimprovement is that $a_k \prec_i a_j$ for some $i \in C \cap D$. Since these two conditions are inconsistent, we can conclude that a strategic disimprovement is impossible.

Now suppose that there is a preferential improvement from an initial state (a_j, C) to a subsequent state (a_k, D). Since we have already shown that disloyalty movement and preferential improvement are mutually exclusive, we show that no agglomeration movement or strategic disimprovement can occur from state (a_j, C) to state (a_k, D). If the movement $(a_j, C) \to (a_k, D)$ is a preferential improvement, then $C = D$ while both agglomeration move and strategic disimprovement entail $C \neq D$. An agglomeration move from state (a_j, C) to state (a_k, D) cannot be a strategic disimprovement because agglomeration move entails $j = k$ whereas $j \neq k$ in each strategic disimprovement. This can complete the proof.

3.2.2 The Likelihood of Movements

If there is no movement from a specific state to another state according to the definitions, then we do not discuss the likelihood. The likelihood of occurrence of different moves is not the same. We now propose some criteria to measure the likelihood of moves.

- *Likelihood of Preferential Improvements:*

We classify all Preferential Improvements into three categories, Possible, Likely and Very Likely to reflect the degree of likelihood. We use two criteria, PI-Likelihood1 and PI-Likelihood2. Consider the Preferential Improvement $(a_j, C) \to (a_k, C)$.

$$\text{PI-Likelihood1} = \begin{cases} 1\ , & P_i(a_j) - P_i(a_k) > 1 \quad \text{for all } i \in C \\ 0\ , & \text{otherwise} \end{cases}$$

If the move represents a major improvement for every decision maker in the coalition, then PI-Likelihood1 = 1.

$$\text{PI-Likelihood2} = \begin{cases} 1, & \text{if } |C| > 1 \\ 0, & \text{otherwise} \end{cases}$$

If the coalition possesses more than one decision maker, then PI-Likelihood2 = 1. Now we define

PI-Likelihood = PI-Likelihood1 + PI-Likelihood2

We say that the Likelihood for Preferential Improvement is Possible if PI-Likelihood = 0 , Likely if PI-Likelihood = 1, and Very Likely if PI-Likelihood = 2

Figure 3.2 shows a flowchart for determining the likelihood of a Preferential Improvement.

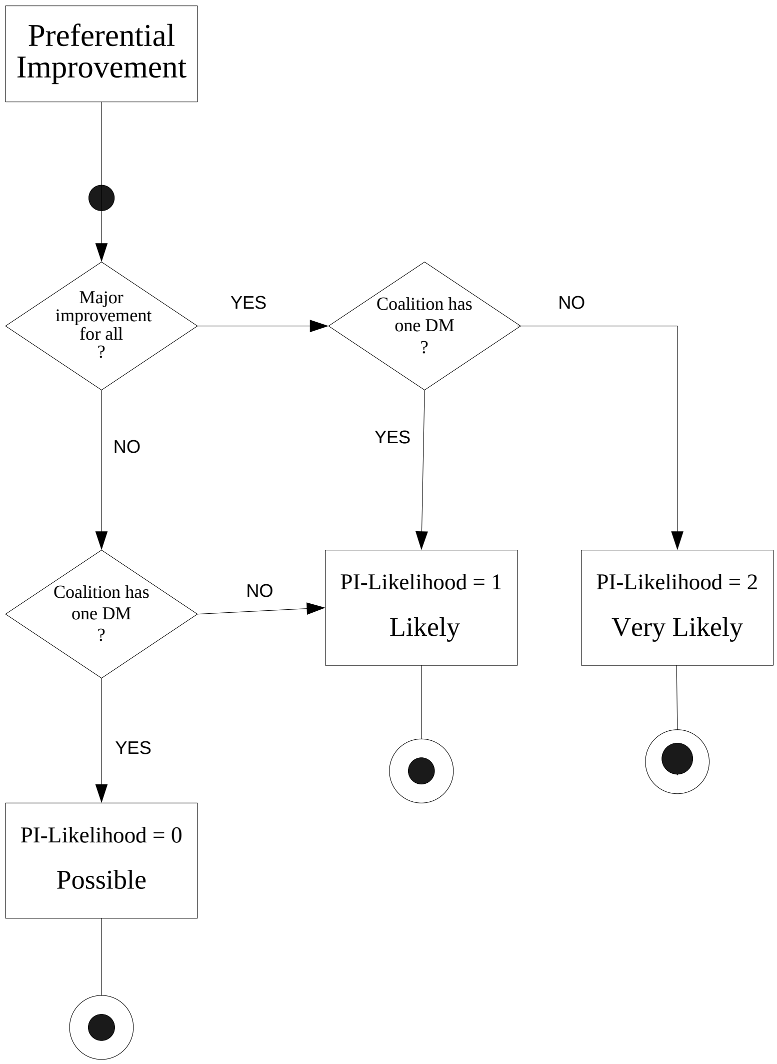

Figure 3.2 - Flowchart for determining the likelihood of a Preferential Improvement

- *The Likelihood of Agglomeration:*

Like Preferential Improvements, we classify Agglomeration movements into three categories, Possible, Likely and Very likely. Consider the Agglomeration movement $(a_j, C) \to (a_j, C')$.

$$\text{AG-Likelihood1} = \begin{cases} 1\ , & \text{if } (a_j, C') \text{ is feasible} \\ 0\ , & \text{otherwise} \end{cases}$$

There is more motivation to move to a feasible state, so if the subsequent state is feasible, then AG-Likelihood1 = 1.

$$\text{AG-Likelihood2} = \begin{cases} 1\ , & \text{if } \mathrm{P_i}(a_j) = 1,\ for \forall i \in C' - C \\ 0\ , & \text{otherwise} \end{cases}$$

Those decision makers who most prefer the alternative have more motivation to join the initial coalition. So if every joining decision maker is highly motivated, then AG-Likelihood2 = 1.

Now define

AG-Likelihood = AG-Likelihood1 + AG-Likelihood2

The Likelihood for Agglomeration movement is Possible if AG-Likelihood = 0 , Likely if AG-Likelihood = 1 , and Very likely if AG-Likelihood = 2 .

- *The Likelihood of Disloyalty:*

We classify all disloyalty movements into three categories, Possible, Likely and Very likely. Consider the disloyalty movement $(a_j, C) \to (a_k, D)$. Define:

$$\text{DL-Likelihood1} = \begin{cases} 1\ , & \text{if } (a_j, C) \text{ is infeasible} \\ 0\ , & \text{otherwise} \end{cases}$$

There is more motivation to move from an infeasible state. Hence, if the initial state is infeasible, DL-Likelihood1 = 1.

$$\text{DL-Likelihood2} = \begin{cases} 1\ , & \mathrm{P_i}(\mathrm{a_k}) \le Acc_i \quad \text{for} \forall i \in D \\ 0\ , & \text{otherwise} \end{cases}$$

If the subsequent alternative is accepted by all decision makers forming the subsequent coalition, then DL-Likelihood2 = 1. Now define

DL-Likelihood = DL-Likelihood1 + DL-Likelihood2

Thus the Likelihood for Disloyalty movement is Possible, if DL-Likelihood=0 , Likely if DL-Likelihood=1 , and Very likely if DL-Likelihood=2 .

- *The Likelihood of Strategic Disimprovement:*

We classify all strategic disimprovements into four categories, Unlikely, Possible, Likely and Very likely. Consider the strategic disimprovement $(a_j, C) \to (a_k, D)$. Define

$$\text{SD-Likelihood1} = \begin{cases} 1\ , & P_i(a_k) \le Acc_i \quad \text{for} \forall i \in C \cap D \\ 0\ , & \text{otherwise} \end{cases}$$

If the subsequent alternative is accepted by all decision makers who move from the initial state to the subsequent one, then SD-Likelihood1 = 1.

$$\text{SD-Likelihood2} = \begin{cases} -1\ , & \exists i \in C \cap D \text{ , such that } a_k \text{ is uniquely worst for i} \\ 0\ , & \text{otherwise} \end{cases}$$

There is strong motivation for a decision maker to avoid his or her uniquely worst alternative. Therefore, if the subsequent alternative is some DM's uniquely worst alternative, then SD-Likelihood2 = -1.

The alternative a_k is considered the uniquely worst alternative for *i* iff $P_i(a_k) = q = |A|$ where $A = \{a_1, a_2, ..., a_q\}$. In other words, an alternative is a uniquely worst for DM *i* if all other alternatives are preferable to it.

For example, consider the following case of preferences:

$i: \quad A \succ B \sim C \sim D$

Since $P_i(B) = P_i(C) = P_i(D) = 2 \ne 4$, then DM *i* does not have a uniquely worst alternative. But in the preferences of $i: \quad A \sim B \sim C \succ D$

$P_i(A) = P_i(B) = P_i(C) = 1 \quad and \quad P_i(D) = 4$. Therefore, D is the uniquely worst alternative for *i*.

$$\text{SD-Likelihood3} = \begin{cases} 1\ , & \text{if } \mathrm{P_i(a_k) = 1} \ , \forall i \in D - C \\ 0\ , & \text{otherwise} \end{cases}$$

Those decision makers who most prefer the subsequent alternative have more motivation to support it. So, if all decision makers who join the initial coalition like the subsequent alternative best, then SD-Likelihood3 = 1.

$$\text{SD-Likelihood} = \text{SD-Likelihood1} + \text{SD-Likelihood2} + \text{SD-Likelihood3}$$

The Likelihood for strategic disimprovements is Unlikely, if SD-Likelihood = -1, Possible if SD-Likelihood = 0, Likely if SD-Likelihood = 1, and Very likely if SD-Likelihood = 2

3.3 Examples

Now, we illustrate these movements from one state to another using some examples.

3.3.1 Example 1

Suppose that three DMs, 1, 2 and 3, are involved in a negotiation to reach an agreement on one alternative among four available alternatives, A, B, D, and E. The preferences of each decision maker over the alternatives are transitive, as follows: (in decreasing order of preference)

$$A \succ_1 B \succ_1 E \succ_1 D$$

$$B \succ_2 E \succ_2 A \succ_2 D$$

$$D \succ_3 E \succ_3 B \succ_3 A$$

The weights of the DMs in negotiation are as follows: $w_1 = 1$, $w_2 = 2$, and $w_3 = 3$. The threshold of agreement is T = 4. Thus, a negotiation state is feasible if the sum of weights of the members of the associated coalition is at least equal to 4.

For this example, there are 28 possible states because there are seven $(2^3 - 1)$ coalitions and each coalition may support one of four possible alternatives. Figure 3.3 shows the 16 infeasible states. The arrows in this figure indicate possible preferential improvements from an infeasible state to another infeasible state. For instance, both DMs 1 and 2 prefer alternatives A, B and E to D. Hence, they may move from alternative D to E or B or A.

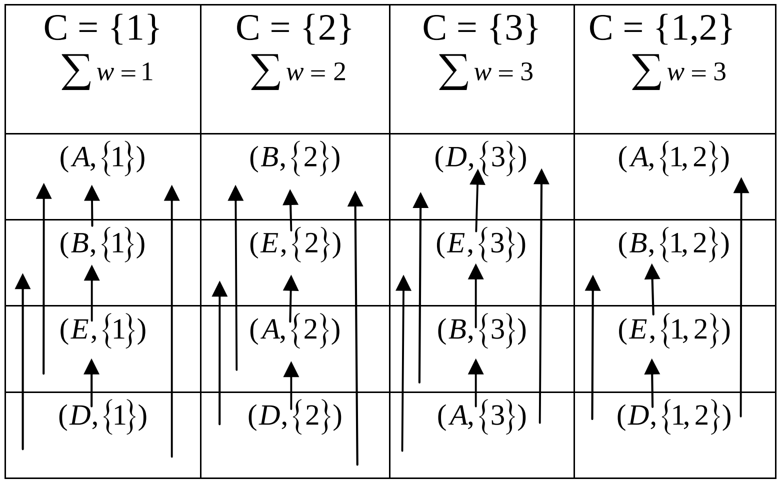

Figure 3.3: Infeasible states and Preferential Improvements among them

Figure 3.4 shows the 12 feasible states.

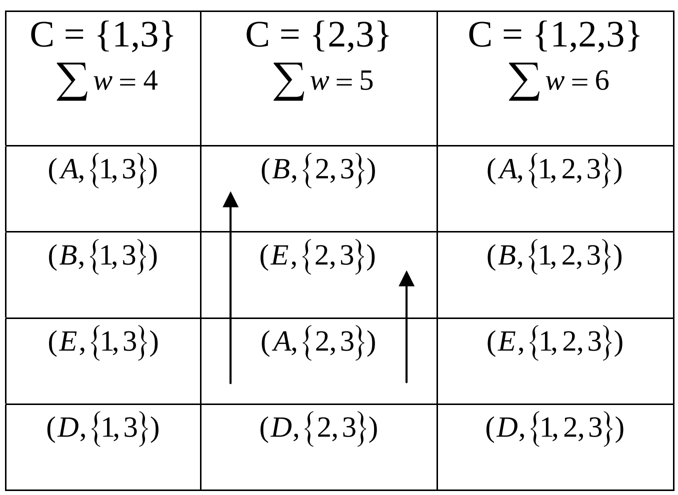

Figure 3.4: Feasible states and Preferential Improvements among them

In tables 3.1 to 3.4, we list all movements that may occur from an initial state to a subsequent state.

Table 3.1: Preferential Improvements in Example 1

Initial State →	Subsequent State	PI-Likelihood1	PI-Likelihood2	PI-Likelihood
$(B,\{1\})$	$(A,\{1\})$	0	0	Possible
$(D,\{1\})$	$(A,\{1\})$	1	0	Likely
$(D,\{1\})$	$(B,\{1\})$	1	0	Likely
$(D,\{1\})$	$(E,\{1\})$	0	0	Possible
$(E,\{1\})$	$(A,\{1\})$	1	0	Likely
$(E,\{1\})$	$(B,\{1\})$	0	0	Possible
$(A,\{2\})$	$(B,\{2\})$	1	0	Likely
$(A,\{2\})$	$(E,\{2\})$	0	0	Possible
$(D,\{2\})$	$(A,\{2\})$	0	0	Possible
$(D,\{2\})$	$(B,\{2\})$	1	0	Likely
$(D,\{2\})$	$(E,\{2\})$	1	0	Likely
$(E,\{2\})$	$(B,\{2\})$	0	0	Possible
$(A,\{3\})$	$(B,\{3\})$	0	0	Possible
$(A,\{3\})$	$(D,\{3\})$	1	0	Likely
$(A,\{3\})$	$(E,\{3\})$	1	0	Likely
$(B,\{3\})$	$(D,\{3\})$	1	0	Likely
$(B,\{3\})$	$(E,\{3\})$	0	0	Possible
$(E,\{3\})$	$(D,\{3\})$	0	0	Possible
$(D,\{1,2\})$	$(A,\{1,2\})$	0	1	Likely
$(D,\{1,2\})$	$(B,\{1,2\})$	1	1	Very Likely
$(D,\{1,2\})$	$(E,\{1,2\})$	0	1	Likely
$(E,\{1,2\})$	$(B,\{1,2\})$	0	1	Likely
$(A,\{2,3\})$	$(B,\{2,3\})$	0	1	Likely

$(A,\{2,3\})$	$(E,\{2,3\})$	0	1	Likely

We further assume that a DM will accept only one of his or her two most preferred alternatives. In other words, $\forall i \in N; Acc_i = 2$. With this assumption, we now list all possible agglomeration movements in Example 1.

Table 3.2: Agglomerations in Example 1

Initial State →	Subsequent State	AG-Likelihood1	AG-Likelihood2	AG-Likelihood
$(B,\{1\})$	$(B,\{1,2\})$	0	1	Likely
$(D,\{1\})$	$(D,\{1,3\})$	1	1	Very Likely
$(E,\{1\})$	$(E,\{1,2\})$	0	0	Possible
$(E,\{1\})$	$(E,\{1,3\})$	1	0	Likely
$(E,\{1\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{2\})$	$(A,\{1,2\})$	0	1	Likely
$(B,\{2\})$	$(B,\{1,2\})$	0	0	Possible
$(D,\{2\})$	$(D,\{2,3\})$	1	1	Very Likely
$(E,\{2\})$	$(E,\{2,3\})$	1	0	Likely
$(A,\{3\})$	$(A,\{1,3\})$	1	1	Very Likely
$(B,\{3\})$	$(B,\{1,3\})$	1	0	Likely
$(B,\{3\})$	$(B,\{2,3\})$	1	1	Very Likely
$(B,\{3\})$	$(B,\{1,2,3\})$	1	0	Likely
$(E,\{3\})$	$(E,\{2,3\})$	1	0	Likely
$(D,\{1,2\})$	$(D,\{1,2,3\})$	1	1	Very Likely

$(E,\{1,2\})$	$(E,\{1,2,3\})$	1	0	Likely
$(B,\{1,3\})$	$(B,\{1,2,3\})$	1	1	Very Likely
$(E,\{1,3\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{2,3\})$	$(A,\{1,2,3\})$	1	1	Very Likely
$(B,\{2,3\})$	$(B,\{1,2,3\})$	1	0	Likely

Now, consider states in which one or more members of the coalition join other DMs outside the coalition to form a new coalition in support of another alternative preferred by the new coalition members such that the news state is feasible. These Disloyalty movements are listed in Table 3.3.

Table 3.3: Disloyalty movements in Example 1

Initial State →	Subsequent State	DL-Likelihood1	DL-Likelihood2	DL-Likelihood
$(A,\{2\})$	$(B,\{2,3\})$	1	0	Likely
$(A,\{2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(A,\{3\})$	$(B,\{2,3\})$	1	0	Likely
$(A,\{3\})$	$(E,\{2,3\})$	1	1	Very Likely
$(A,\{1,2\})$	$(B,\{2,3\})$	1	0	Likely
$(A,\{1,2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(A,\{1,3\})$	$(B,\{2,3\})$	0	0	Possible
$(A,\{1,3\})$	$(E,\{2,3\})$	0	1	Likely
$(A,\{1,2,3\})$	$(B,\{2,3\})$	0	0	Possible
$(A,\{1,2,3\})$	$(E,\{2,3\})$	0	1	Likely

Strategic disimprovements occur when one or more members of the initial coalition agree to move from an infeasible state to a feasible one, even though the new alternative is less preferable than the initial one. In this example, we suppose that all DMs accept at most one level of disimprovement from their initial position. In other words, $FD_i = 1$ for i = 1, 2, 3. For example, DM 1, who likes agreement A best may accept agreement B - his second best alternative- when other DMs support it but will not accept agreement E - his third best - even if other DMs support it. The strategic disimprovements are listed in Table 3.4.

Table 3.4: Strategic Disimprovements in Example 1

Initial State →	SubsequentState	SD-Likelihood1	SD-Likelihood2	SD-Likelihood3	SD-Likelihood
$(B,\{1\})$	$(E,\{1,3\})$	0	0	0	Possible
$(B,\{1\})$	$(E,\{1,2,3\})$	0	0	0	Possible
$(E,\{1\})$	$(D,\{1,3\})$	0	-1	1	Possible
$(A,\{2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(B,\{2\})$	$(E,\{2,3\})$	1	0	0	Likely
$(B,\{3\})$	$(A,\{1,3\})$	0	-1	1	Possible
$(D,\{3\})$	$(E,\{2,3\})$	1	0	0	Likely
$(E,\{3\})$	$(B,\{1,3\})$	0	0	0	Possible
$(E,\{3\})$	$(B,\{2,3\})$	0	0	1	Likely
$(E,\{3\})$	$(B,\{1,2,3\})$	0	0	0	Possible
$(A,\{1,2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(B,\{1,2\})$	$(E,\{1,3\})$	0	0	0	Possible
$(B,\{1,2\})$	$(E,\{2,3\})$	1	0	0	Likely
$(B,\{1,2\})$	$(E,\{1,2,3\})$	0	0	0	Possible
$(E,\{1,2\})$	$(D,\{1,3\})$	0	-1	1	Possible

There are no movements from the unanimous agreements over the alternatives B, E, and D. In other words, the states $(B,\{1,2,3\})$, $(E,\{1,2,3\})$ and $(D,\{1,2,3\})$ are stable. $(E,\{2,3\})$, $(D,\{1,3\})$ and $(D,\{2,3\})$ are stable states for the similar reason. Also, $(A,\{1\})$ is a stable state, even though, it is not feasible. In other words, we cannot predict any particular feasible agreement, if we began at a status quo in which decision maker 1 supports A.

There is no movement to states $(D,\{1\})$, $(D,\{2\})$, $(A,\{3\})$, $(D,\{1,2\})$ and $(A,\{2,3\})$ from any other state, but there are very likely movements from these states to others. Therefore, these negotiation states are unstable.

Now, suppose that the initial state is $(E,\{2\})$. In figure 3.5, we trace movements from this state. Note that movements from state $(E,\{2\})$ cannot lead to an agreement on alternative A. Also, the model indicates that the feasible state $(E,\{2,3\})$ is more likely to occur than the feasible state $(E,\{1,2,3\})$.

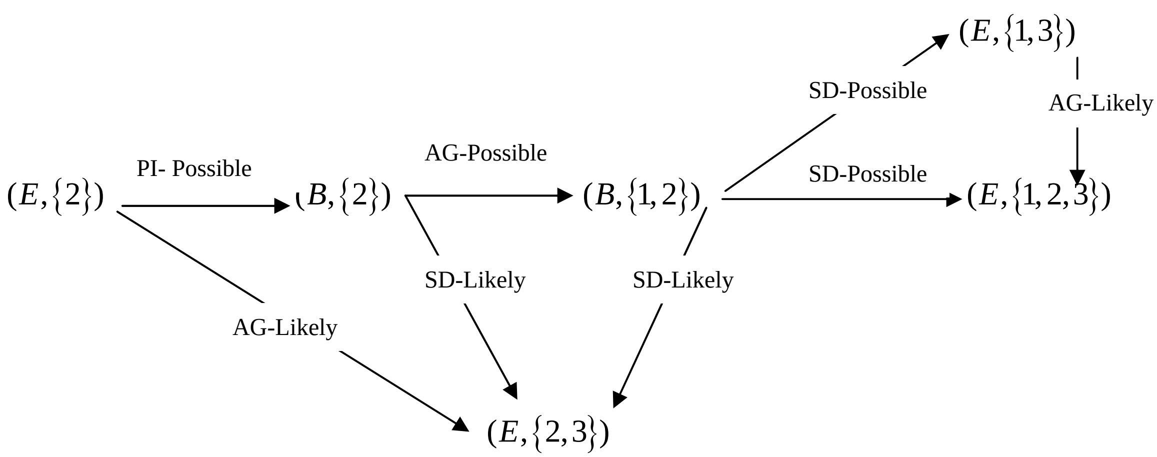

Figure 3.5: A tree of possible movements from a given state to other states

To answer the question that to what extent the state $(E,\{2,3\})$ is more likely to occur than the state $(E,\{1,2,3\})$, we define the Likelihood Measure. A Likelihood Measure is a number associated with each potential outcome of a negotiation and indicates the possibility that a state occur as the final outcome of the negotiation. Suppose that we ascribe a subjective probability like 20%, 40%, 60% and 80% to each one of Unlikely, Possible, Likely and Very Likely movements, respectively.

Based on the tree illustrated in Figure 3.5, we can determine the Likelihood Measure for potential outcomes of the negotiation explained in Example 1.

$(E,\{2,3\}) \longrightarrow$ (0.6) + (0.4) (0.6) + (0.4) (0.4) (0.6) = 0.936

$(E,\{1,2,3\}) \longrightarrow$ (0.4)(0.4)(0.4) + (0.4) (0.4) (0.4) (0.6) = 0.102

Since sum of 0.936 and 0.102 is more than 1, we normalize them such that their sum becomes 1. Table 3.5 shows the Likelihood Measures for potential outcomes of the negotiation explained in Example 1. Notice that the Likelihood Measure is not a probability.

Table 3.5: Likelihood Measure for Example 1

potential outcome	Likelihood Measure
$(E,\{2,3\})$	0.902
$(E,\{1,2,3\})$	0.098

3.3.2 Example 2

In the previous example, make the following changes:

- DM 2 is indifferent between alternatives A and D and DM 3 is indifferent between alternatives D and E.
- $w_1 = w_2 = 1.5$
- The threshold of agreement for alternative B is T = 5.
- Fallback distance for DM 1 is 2.

Other conditions of this negotiation model are as in Example 1. Recall that the preferences of the decision maker over the alternatives are as follows:

$A \succ_1 B \succ_1 E \succ_1 D$

$B \succ_2 E \succ_2 A \sim_2 D$

$D \sim_3 E \succ_3 B \succ_3 A$

We now analyze how the possible movements and their associated likelihoods will change under the new conditions. Table 3.6 – 3.9 list all types of movements for Example 2.

Table 3.6: Preferential Improvements in Example 2

Initial State	Subsequent State	PI-Likelihood1	PI-Likelihood2	PI-Likelihood
$(B,\{1\})$	$(A,\{1\})$	0	0	Possible
$(D,\{1\})$	$(A,\{1\})$	1	0	Likely
$(D,\{1\})$	$(B,\{1\})$	1	0	Likely
$(D,\{1\})$	$(E,\{1\})$	0	0	Possible
$(E,\{1\})$	$(A,\{1\})$	1	0	Likely
$(E,\{1\})$	$(B,\{1\})$	0	0	Possible
$(A,\{2\})$	$(B,\{2\})$	1	0	Likely
$(A,\{2\})$	$(E,\{2\})$	0	0	Possible
$(D,\{2\})$	$(B,\{2\})$	1	0	Likely
$(D,\{2\})$	$(E,\{2\})$	0	0	Possible
$(E,\{2\})$	$(B,\{2\})$	0	0	Possible
$(A,\{3\})$	$(B,\{3\})$	0	0	Possible
$(A,\{3\})$	$(D,\{3\})$	1	0	Likely
$(A,\{3\})$	$(E,\{3\})$	1	0	Likely

$(B,\{3\})$	$(D,\{3\})$	1	0	Likely
$(B,\{3\})$	$(E,\{3\})$	1	0	Likely
$(D,\{1,2\})$	$(A,\{1,2\})$	0	1	Likely
$(D,\{1,2\})$	$(B,\{1,2\})$	1	1	Very Likely
$(D,\{1,2\})$	$(E,\{1,2\})$	0	1	Likely
$(E,\{1,2\})$	$(B,\{1,2\})$	0	1	Likely
$(D,\{1,3\})$	$(E,\{1,3\})$	0	1	Likely
$(A,\{2,3\})$	$(B,\{2,3\})$	0	1	Likely
$(A,\{2,3\})$	$(D,\{2,3\})$	0	1	Likely
$(A,\{2,3\})$	$(E,\{2,3\})$	0	1	Likely
$(D,\{2,3\})$	$(E,\{2,3\})$	0	1	Likely
$(D,\{1,2,3\})$	$(E,\{1,2,3\})$	0	1	Likely

Table 3.7: Agglomerations in Example 2

Initial State	Subsequent State	AG-Likelihood1	AG-Likelihood2	AG-Likelihood
$(B,\{1\})$	$(B,\{1,2\})$	0	1	Likely
$(D,\{1\})$	$(D,\{1,3\})$	1	1	Very Likely
$(E,\{1\})$	$(E,\{1,2\})$	0	0	Possible
$(E,\{1\})$	$(E,\{1,3\})$	1	1	Very Likely
$(E,\{1\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{2\})$	$(A,\{1,2\})$	0	1	Likely
$(B,\{2\})$	$(B,\{1,2\})$	0	0	Possible
$(D,\{2\})$	$(D,\{2,3\})$	1	1	Very Likely
$(E,\{2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(A,\{3\})$	$(A,\{1,3\})$	1	1	Very Likely
$(B,\{3\})$	$(B,\{1,3\})$	0	0	Possible
$(B,\{3\})$	$(B,\{2,3\})$	0	1	Likely
$(B,\{3\})$	$(B,\{1,2,3\})$	1	0	Likely
$(E,\{3\})$	$(E,\{2,3\})$	1	0	Likely
$(D,\{1,2\})$	$(D,\{1,2,3\})$	1	1	Very Likely
$(E,\{1,2\})$	$(E,\{1,2,3\})$	1	1	Very Likely
$(B,\{1,3\})$	$(B,\{1,2,3\})$	1	1	Very Likely
$(E,\{1,3\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{2,3\})$	$(A,\{1,2,3\})$	1	1	Very Likely
$(B,\{2,3\})$	$(B,\{1,2,3\})$	1	0	Likely

Table 3.8: Disloyalty movements in Example 2

Initial State	Subsequent State	DL-Likelihood1	DL-Likelihood2	DL-Likelihood
$(D,\{1\})$	$(E,\{1,3\})$	1	0	Likely
$(D,\{1\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{2\})$	$(D,\{2,3\})$	1	0	Likely
$(A,\{2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{2\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{3\})$	$(D,\{2,3\})$	1	0	Likely
$(A,\{3\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{3\})$	$(E,\{1,3\})$	1	0	Likely
$(D,\{3\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{3\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{1,2\})$	$(D,\{2,3\})$	1	0	Likely
$(A,\{1,2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{1,2\})$	$(E,\{1,3\})$	1	0	Likely
$(D,\{1,2\})$	$(E,\{2,3\})$	1	1	Very Likely
$(D,\{1,2\})$	$(E,\{1,2,3\})$	1	0	Likely
$(A,\{1,3\})$	$(D,\{2,3\})$	0	0	Possible
$(A,\{1,3\})$	$(E,\{2,3\})$	0	1	Likely
$(D,\{1,3\})$	$(E,\{2,3\})$	0	1	Likely
$(D,\{1,3\})$	$(E,\{1,2,3\})$	0	0	Possible
$(D,\{2,3\})$	$(E,\{1,3\})$	0	0	Possible
$(D,\{2,3\})$	$(E,\{1,2,3\})$	0	0	Possible
$(A,\{1,2,3\})$	$(D,\{2,3\})$	0	0	Possible
$(A,\{1,2,3\})$	$(E,\{2,3\})$	0	1	Likely

$(D,\{1,2,3\})$	$(E,\{1,3\})$	0	0	Possible
$(D,\{1,2,3\})$	$(E,\{2,3\})$	0	1	Likely

Table 3.9: Strategic Disimprovements in Example 2

Initial State	Subsequent State	SD-Likelihood1	SD-Likelihood2	SD-Likelihood3	SD-Likelihood
$(A,\{1\})$	$(E,\{1,3\})$	0	0	1	Likely
$(A,\{1\})$	$(E,\{1,2,3\})$	0	0	0	Possible
$(B,\{1\})$	$(D,\{1,3\})$	0	-1	1	Possible
$(B,\{1\})$	$(E,\{1,3\})$	0	0	1	Likely
$(B,\{1\})$	$(E,\{1,2,3\})$	0	0	0	Possible
$(E,\{1\})$	$(D,\{1,3\})$	0	-1	1	Possible
$(B,\{2\})$	$(E,\{2,3\})$	1	0	1	Very Likely
$(E,\{2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(B,\{3\})$	$(A,\{1,3\})$	0	-1	1	Possible
$(A,\{1,2\})$	$(E,\{1,3\})$	0	0	1	Likely
$(A,\{1,2\})$	$(E,\{1,2,3\})$	0	0	1	Likely
$(B,\{1,2\})$	$(D,\{1,3\})$	0	-1	1	Possible
$(B,\{1,2\})$	$(E,\{1,3\})$	0	0	1	Likely
$(B,\{1,2\})$	$(E,\{2,3\})$	1	0	1	Very Likely
$(B,\{1,2\})$	$(E,\{1,2,3\})$	0	0	1	Likely
$(E,\{1,2\})$	$(D,\{1,3\})$	0	-1	1	Possible
$(E,\{1,2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(E,\{1,2\})$	$(D,\{1,2,3\})$	0	-1	1	Possible
$(B,\{1,3\})$	$(E,\{1,2,3\})$	0	0	0	Possible
$(B,\{2,3\})$	$(A,\{1,3\})$	0	-1	1	Possible

There is no movement from the unanimous agreements over the alternatives B and E, so that states $(B,\{1,2,3\})$ and $(E,\{1,2,3\})$ are stable. The only other stable state is $(E,\{2,3\})$. Compared with the Example 1, the number of stable states in this example is reduced due to the larger number of movements.

Suppose again that the initial state is $(E,\{2\})$. In Figure 3.6, we trace subsequent movements from this state.

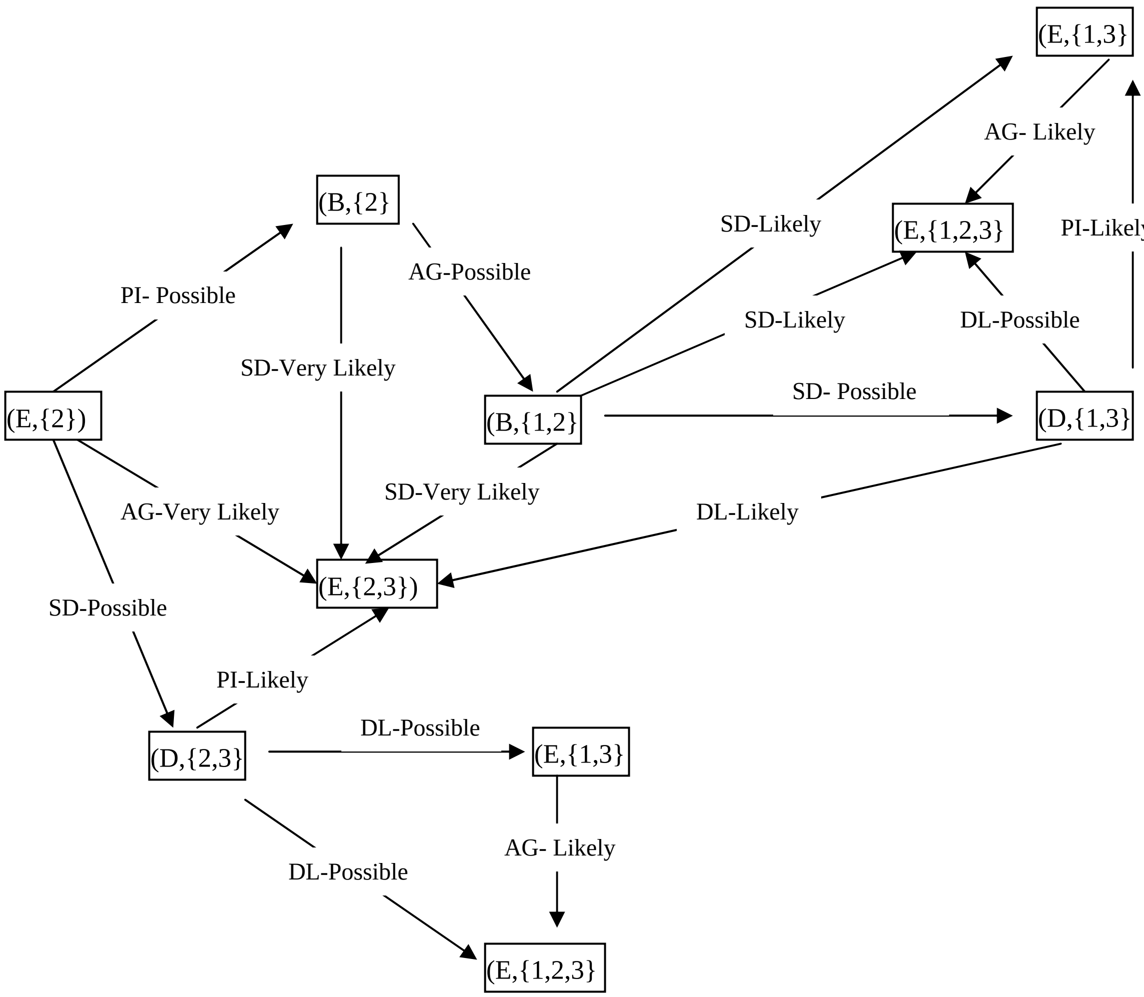

Figure 3.6: A tree of possible movements for Example 2

Although Figure 3.6 shows some changes in movements due to the changes in input data, it indicates that the ultimate outcomes of the negotiation are the same. This figure shows feasible states $(E,\{2,3\})$ and $(E,\{1,2,3\})$ as the likely outcomes of the negotiation and indicates that $(E,\{2,3\})$ is still predicted as the most likely state. The likelihood measures for these two states are:

$(E,\{2,3\}) \longrightarrow$ (0.8) + (0.4) (0.8) + (0.4) (0.6) + (0.4) (0.4) (0.8) + (0.4) (0.4) (0.4) (0.6) = 1.5264

$(E,\{1,2,3\}) \longrightarrow$ (0.4) (0.4) + (0.4) (0.4) (0.6) + (0.4) (0.4) (0.6) + (0.4) (0.4) (0.4) (0.4) + (0.4) (0.4) (0.6) (0.6) + (0.4) (0.4) (0.4) (0.6) (0.6) = 0.45824

Table 3.10 shows the normalized Likelihood Measures for potential outcomes of the negotiation explained in Example 2.

Table 3.10: Likelihood Measure for Example 2

potential outcome	Likelihood Measure
$(E,\{2,3\})$	0.769
$(E,\{1,2,3\})$	0.231

3.4 Sensitivity Analyses

A sensitivity analysis is used to assess whether or not possible revisions in DMs' preferences and unforeseen changes in the model can affect the conclusions of the analysis. For example, a range of possible preferences can be analyzed to ascertain how the likely outcomes of a negotiation are affected. If the results do not change when preferences are slightly modified, the results of the analysis are robust, and one can have greater confidence in them. Alternatively, when a small change in the input data causes a dramatic change in the output of the model, then the analyst should ensure that the model is as accurate and reliable as possible before drawing conclusions. The followings are some types of sensitivity analysis that could be applied in modeling negotiations:

- Alternative modification or expansion
- Alternative' threshold change
- DM's preference changes
- DM's weight change
- DM's fallback distance change
- DM's acceptability change

There are a number of ways to do a Sensitivity Analysis, including a systematic Exhaustive Sensitivity Analysis in which one examines the effects of all possible changes in model parameters. Alternatively, one can identify the most plausible parameter changes and then determine how they affect the results. A systematic exhaustive sensitivity analysis usually entails a very large number of individual calculations and is therefore not easy to do. For example, in Example 1 in Section 3.3.1, the number of all possible changes in one player's preference orders is (4! –1) + (4! –1) + (4! -1) = 69. If one desires to execute an exhaustive sensitivity analysis for the Fallback Distance of a DM in that example, he or she would carry out (4 -1) *3 = 9 repetitions of the sensitivity analysis, as each DM's Fallback Distance can be 0, 1, 2, or 3 and we have 3 DMs. Example 1 in Section 3.3.1 is a simple model. An exhaustive sensitivity analysis for more practical models like the Caspian Sea negotiations - which will be discussed in Chapter 5 – would be an enormous task to undertake.

In the following sections, we implement some minor changes in input data of Example 1 to evaluate to what extent the results will be changed.

3.4.1 Sensitivity Analysis 1

We change only DM 3's preferences over his acceptable alternatives, so the preferences of each decision maker over the alternatives are as follows:

$A \succ_1 B \succ_1 E \succ_1 D$

$B \succ_2 E \succ_2 A \succ_2 D$

$E \succ_3 D \succ_3 B \succ_3 A$

\- - - - - - - -

The weights of the DMs in negotiation are not changed and are as follows: $w_1 = 1$, $w_2 = 2$, and $w_3 = 3$. The threshold of agreement is again T = 4. Table 3.11 shows the stable states of sensitivity analysis 1.

Table 3.11: The stable states of Sensitivity Analysis 1

Stable state	Feasibility status
$(A,\{1\})$	Infeasible
$(E,\{2,3\})$	Feasible
$(B,\{1,2,3\})$	Feasible
$(E,\{1,2,3\})$	Feasible

Due to the change in DM 3's preferences, the total number of movements increases and the number of stable states decreases. As Table 3.11 indicates, the states $(D,\{1,2,3\})$, $(D,\{1,3\})$ and $(D,\{2,3\})$ which were stable in Example 1, are no longer stable.

Now, suppose that the initial state is $(E,\{2\})$. In figure 3.7, we trace all subsequent movements from this initial state. Like Example 1, feasible states $(E,\{2,3\})$ and $(E,\{1,2,3\})$ are the likely outcomes of the negotiation and $(E,\{2,3\})$ is still predicted as the most likely state. Although minor changes are seen in the likelihood of movements, there is no significant difference between the movements in Figure 3.7 and those shown in Figure 3.5.

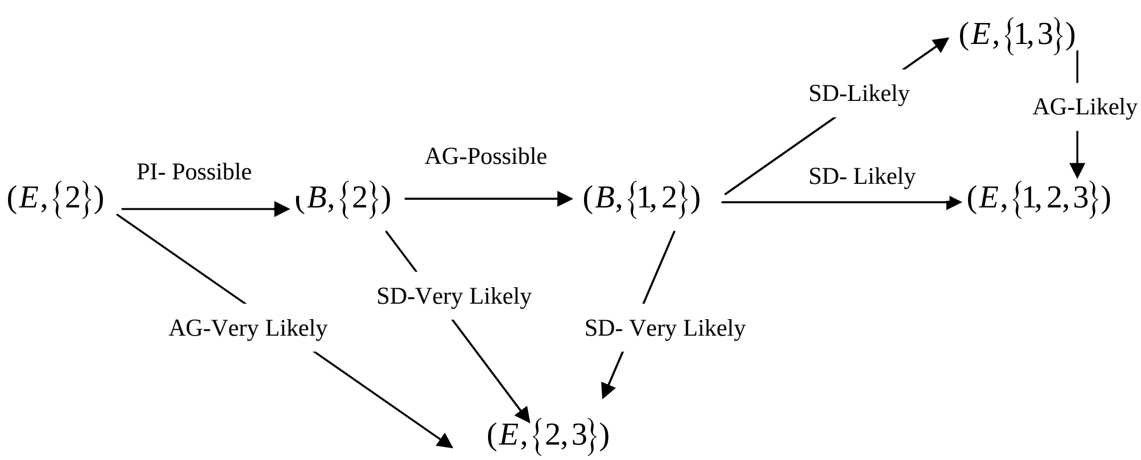

Figure 3.7: A tree of possible movements for Sensitivity Analysis 1

Table 3.12 shows the normalized Likelihood Measures for potential outcomes of the negotiation explained in sensitivity analysis 1.

Table 3.12: Likelihood Measure for sensitivity analysis 1

potential outcome	Likelihood Measure
$(E,\{2,3\})$	0.89
$(E,\{1,2,3\})$	0.11

If we compare the Likelihood Measure for Sensitivity Analysis 1 with those of Example 1, we observe just a slight difference.

3.4.2 Sensitivity Analysis 2

We replace the preferences of the second preferred and the third preferred alternatives of DM 2. So, the preferences of each decision maker over the alternatives are as follows:

$A \succ_1 B \succ_1 E \succ_1 D$

$B \succ_2 \underline{A \succ_2 E} \succ_2 D$

$D \succ_3 E \succ_3 B \succ_3 A$

All other conditions of this negotiation model are identical to Example 1.

All possible movements and their associated likelihoods are analyzed to evaluate to what extent the results will be changed under the new preferences. Table 3.13 shows the stable states based on the movements:

Table 3.13: The stable states of Sensitivity Analysis 2

Stable state	Feasibility status
$(D,\{3\})$	Infeasible
$(D,\{1,3\})$	Feasible
$(E,\{1,3\})$	Feasible
$(D,\{2,3\})$	Feasible
$(E,\{2,3\})$	Feasible
$(B,\{1,2,3\})$	Feasible
$(D,\{1,2,3\})$	Feasible
$(E,\{1,2,3\})$	Feasible

As Table 3.13 indicates, the state $(A,\{1\})$ which was stable in Example 1 is no longer stable because there is an agglomeration move from this state to state $(A,\{1,2\})$. Instead, the state $(D,\{3\})$ which was unstable in Example 1 due to a strategic disimprovement to the state $(E,\{2,3\})$ is now stable. Also, the state $(E,\{1,3\})$ which was unstable in Example 1 due to an agglomeration move to $(E,\{1,2,3\})$ is now stable because the alternative E is no longer acceptable for DM 2.

Again suppose that the initial state is $(E,\{2\})$. In Figure 3.8, we trace all subsequent movements from this state.

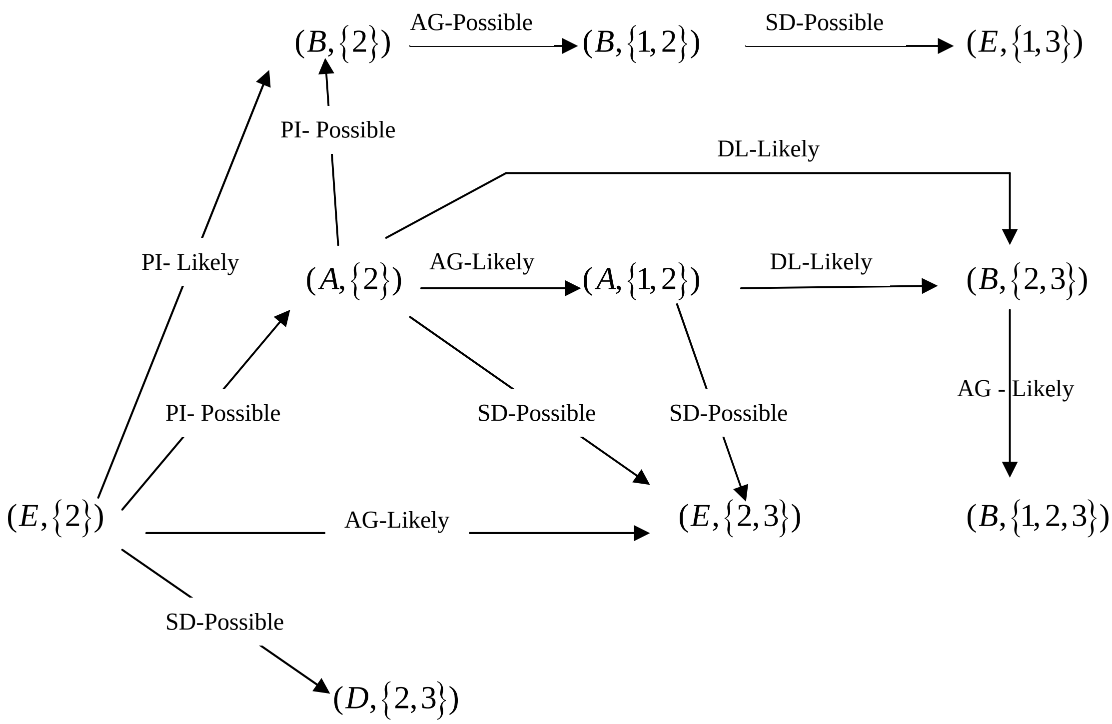

Figure 3.8: A tree of possible movements for Sensitivity Analysis 2

Figure 3.8 shows that feasible states $(E,\{1,3\})$, $(E,\{2,3\})$, $(D,\{2,3\})$ and $(B,\{1,2,3\})$ are the likely outcomes of negotiation. Table 3.14 shows the normalized Likelihood Measures for potential outcomes of the negotiation in Sensitivity Analysis 2.

Table 3.14: Likelihood Measure for Sensitivity Analysis 2

potential outcome	Likelihood Measure
$(E,\{1,3\})$	0.076
$(E,\{2,3\})$	0.532
$(D,\{2,3\})$	0.249
$(B,\{1,2,3\})$	0.143

There are quite a few changes in the results of this example as compared with those of Example 1. Hence, predictions of the ultimate outcome of the negotiation if the status quo is $(E,\{2\})$ are more difficult. However, Table 3.5 indicates that the state $(E,\{2,3\})$ is still the most likely outcome of negotiation. Additionally, if we compare the changes in the results of this sensitivity analysis with those of Sensitivity Analysis 1 we see that the changes here are more significant. This conclusion is plausible because in Sensitivity Analysis 1 we reversed the preferences of two acceptable alternatives of DM 3 while in Sensitivity Analysis 2 we did reversed the preference of an acceptable alternative with that of a non-acceptable one of DM 2.

3.4.3 Sensitivity Analysis 3

We now suppose that $\mathrm{Acc}_2 = 3$. In other words, Decision Maker 2 accepts his or her top three preferred alternatives, rather than only the top two alternatives. The preferences of decision makers over the alternatives and other conditions of the negotiation are identical to Example 1.

This change does not affect preferential improvements and their likelihoods because preferential improvements are not related to the acceptability but the number of agglomerations increases due to DM 2 accepting more alternatives.

Disloyalty movements are exactly identical to disloyalty movements in Example 1 because the preferences of decision makers over the alternatives are the same as Example 1, whereas the number of strategic disimprovements increases due to DM 2 accepting more alternatives.

The stable states are identical to the stable states of Example 1, except that the infeasible state $(A,\{1\})$ is not stable here. The tree of possible movements from the initial state $(E,\{2\})$ to other states is exactly as in Example 1. In other words, the model indicates that the feasible states $(E,\{2,3\})$ and $(E,\{1,2,3\})$ are the likely outcomes of the negotiation provided that the initial state is $(E,\{2\})$. Additionally, $(E,\{2,3\})$ is more likely to occur than $(E,\{1,2,3\})$. Hence, we can conclude that the model is not sensitive to the extension of acceptability of decision maker 2, at least when the initial state is $(E,\{2\})$.

3.4.4 Sensitivity Analysis 4

We now suppose that $FD_1 = 0$. In other words, decision maker 1 will not accept falling back to a less preferred alternative.

Fallback distance is used only to determine strategic disimprovements. Therefore, change in this parameter does not cause any change in other types of movements. Thus, all movements in this example except for strategic disimprovements are identical to those in Example 1, shown in Tables 3.1 to 3.3.

Since FD_1 is less than that in Example 1, the number of strategic disimprovements decreases. Table 3.15 illustrates the remaining strategic disimprovements.

Table 3.15: Strategic Disimprovements for Sensitivity Analysis 4

Initial State →	Subsequent State	SD-Likelihood1	SD-Likelihood2	SD-Likelihood3	SD-Likelihood
$(A,\{2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(B,\{2\})$	$(E,\{2,3\})$	1	0	0	Likely
$(B,\{3\})$	$(A,\{1,3\})$	0	-1	1	Possible
$(D,\{3\})$	$(E,\{2,3\})$	1	0	0	Likely
$(E,\{3\})$	$(B,\{1,3\})$	0	0	0	Possible
$(E,\{3\})$	$(B,\{2,3\})$	0	0	1	Likely
$(E,\{3\})$	$(B,\{1,2,3\})$	0	0	0	Possible
$(A,\{1,2\})$	$(D,\{2,3\})$	0	-1	1	Possible
$(B,\{1,2\})$	$(E,\{2,3\})$	1	0	0	Likely

The stable states are exactly identical to those of Example 1. Figure 3.9 shows the tree of possible movements from the initial state $(E,\{2\})$ to other states.

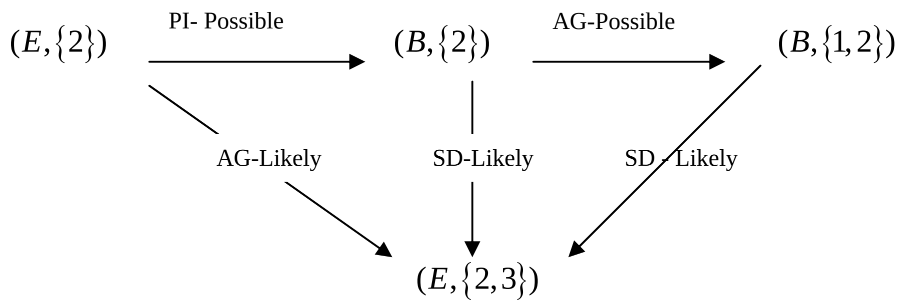

Figure 3.9: A tree of possible movements for Sensitivity Analysis 4

As Figure 3.9 indicates, the only predicted outcome of the negotiation is $(E,\{2,3\})$, which is feasible and stable. Unlike Example 1, the state $(E,\{1,2,3\})$, which indicates on a unanimous agreement over the alternative E, is not predicted as possible outcome, due to the fact that E is not an acceptable alternative according to DM 1 who now refuses to fall back.

3.5 Summary

This chapter is devoted to proposing a new methodology in order to model and analyze a specific structure of multilateral negotiations. Six new concepts are defined in this chapter to pave the construction of the proposed methodology which is based on four types of movements from unstable states to stable ones. Some criteria are proposed to measure the likelihood of different moves. A theorem proved in this chapter shows that all four defined movements are mutually exclusive. It is illustrated how the proposed methodology is applied in order to predict the most likely outcomes of multilateral negotiations using some examples. Four cases of sensitivity analysis are applied to assess whether sudden or unforeseen changes in the model do not affect the conclusion of stability analyses. In Chapter 4 we explain how a negotiation support system for the proposed methodology can be designed and implemented.

Chapter 4

Negotiation Support System for the New Methodology

4-1 Motivation

In the previous chapter, we developed a conceptual model for multilateral negotiations. In this chapter, we will develop a practical Negotiation Support System (NSS). The following are the most important motivations to design and implement a NSS:

- General ideas about movements and their associated likelihoods must be developed and converted to precise definitions and a clear methodology in order to be studied in detail. To refine these raw ideas we need to obtain and observe tangible outputs, which will encourage us to refine or modify definitions and methodologies as appropriate.
- In most real-world problems, there is a great deal of data. Evaluations of the movements and their associated likelihoods in these cases are very time consuming. NSS increases the speed of calculations, as well as helping us to avoid mistakes in manual calculations.
- For applications and for refinement of definitions, we need sensitivity analysis. It is important to understand the effects of small changes in input data on the predicted outcomes of the negotiation. With automatic calculations, we do not need to recalculate the entire model when just one input datum changes.

4-2 Design

Since the concept and components of the proposed Negotiation Support System are similar to those of a Decision Support System, we review the main components of a decision support system in Figure 4.1.

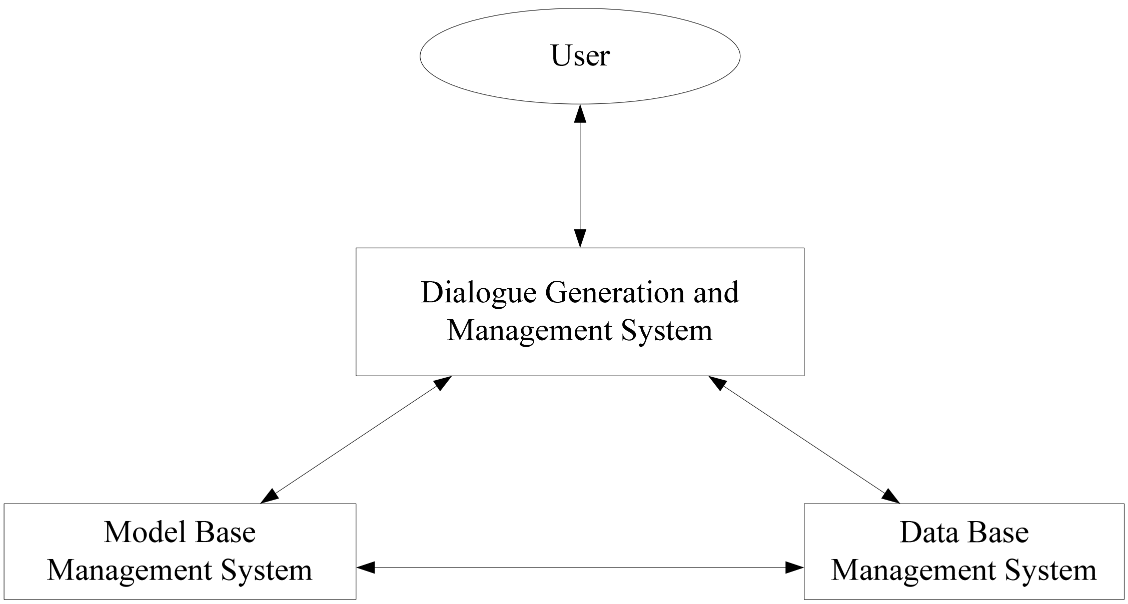

Figure 4.1 - Main components of a decision support system as defined by Sage (1991)

We start from an Entity Relationship Model to design a data-model in order to implement a database which is driven in Microsoft Access. Then we use Microsoft Visual Basic 6 to carry out the definitions and methodology, which are implemented in Business Logic and User Interface layers. Business logic is a non-technical term generally used to describe the functional algorithms that handle information exchange between a database and a user interface. The user interface (or Human Machine Interface) constitutes the means by which the users interact with a system, which may be a machine, a device, a computer program or some other complex tools.

An entity-relationship (ER) diagram illustrates the interrelationships among entities. An entity is something about which data is collected, stored, and maintained. Figure 4.2 shows some of the symbols which are mostly used in ER diagrams to show relationship types between entities.

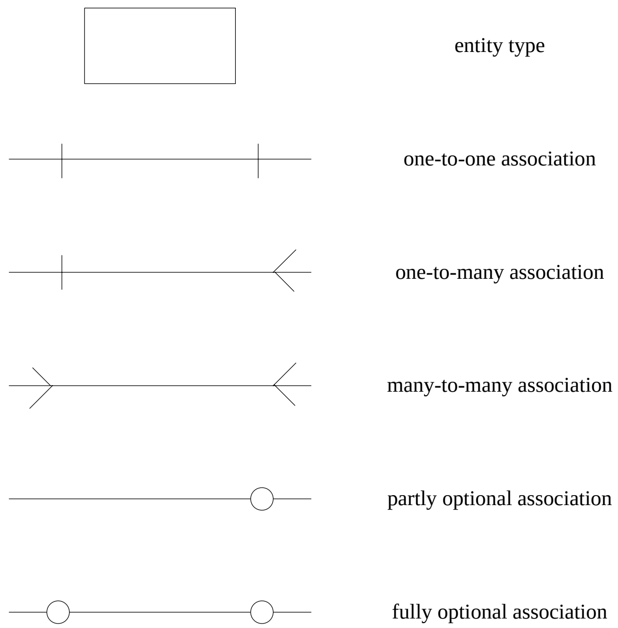

Figure 4.2 – Symbols of ER diagrams

Source: Oracle8*i* Java Stored Procedures Developer's Guide
http://lbdwww.epfl.ch/f/teaching/courses/oracle8i/java.815/a64686/05_dev1.htm

Figures 4.3 illustrates examples of different relations between the entities A and B. Sections (a) and (b) of this Figure represent “one-to-many” and “one-to-one” relations, respectively. More specifically, section (a) indicates that one A is associated with one or more Bs. Section (b) implies that one B is associated with zero or one A.

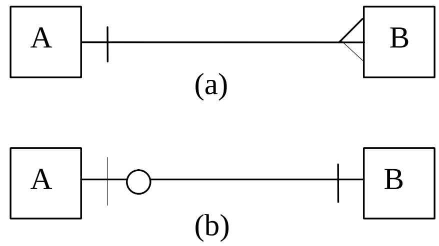

Figure 4.3 – Examples of different relations between entities

Figure 4.4 illustrates the Entity Relationship Diagram for the proposed NSS.

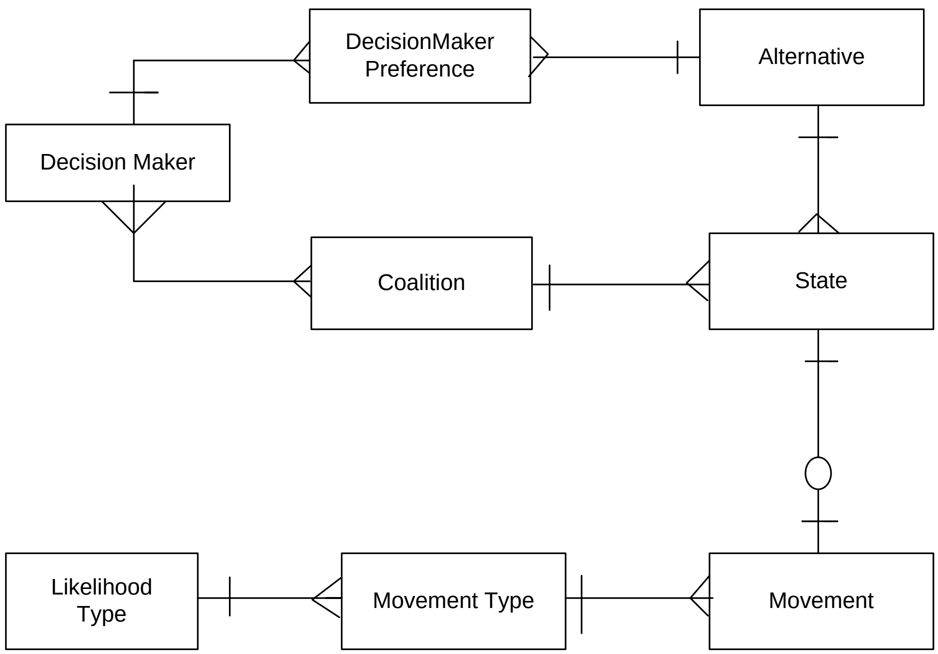

Figure 4.4 - Entity Relationship Diagram for the proposed NSS

As Figure 4.4 shows, each state includes just one coalition but each coalition can be ascribed to several states. The relation between Decision Maker and Coalition entities is originally "many-to-many", meaning that each decision maker may be found in several coalitions and each coalition may include several decision makers. This "many-to-many" relationship is decomposed to two "one-to-many" relationships creating a link entity called "CoalitionDecisionMaker".

Figure 4.5 shows the information flow among the user interface, the input data, the analysis engine of the proposed NSS, and the output data.

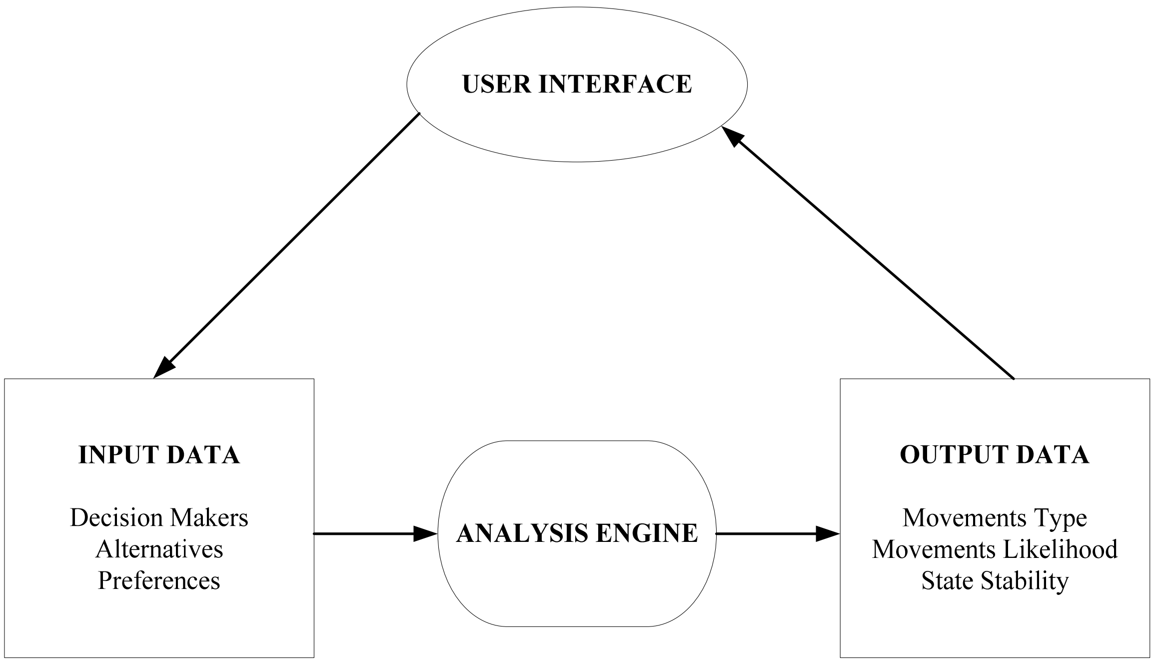

Figure 4.5 - The structure of the proposed Negotiation Support System (Adapted from Fang, *et. al.*, 2003).

Figure 4.6 shows a Data Model Diagram for the proposed NSS. A data model illustrates the organization and relationships among data in a manner that reflects the information structure.

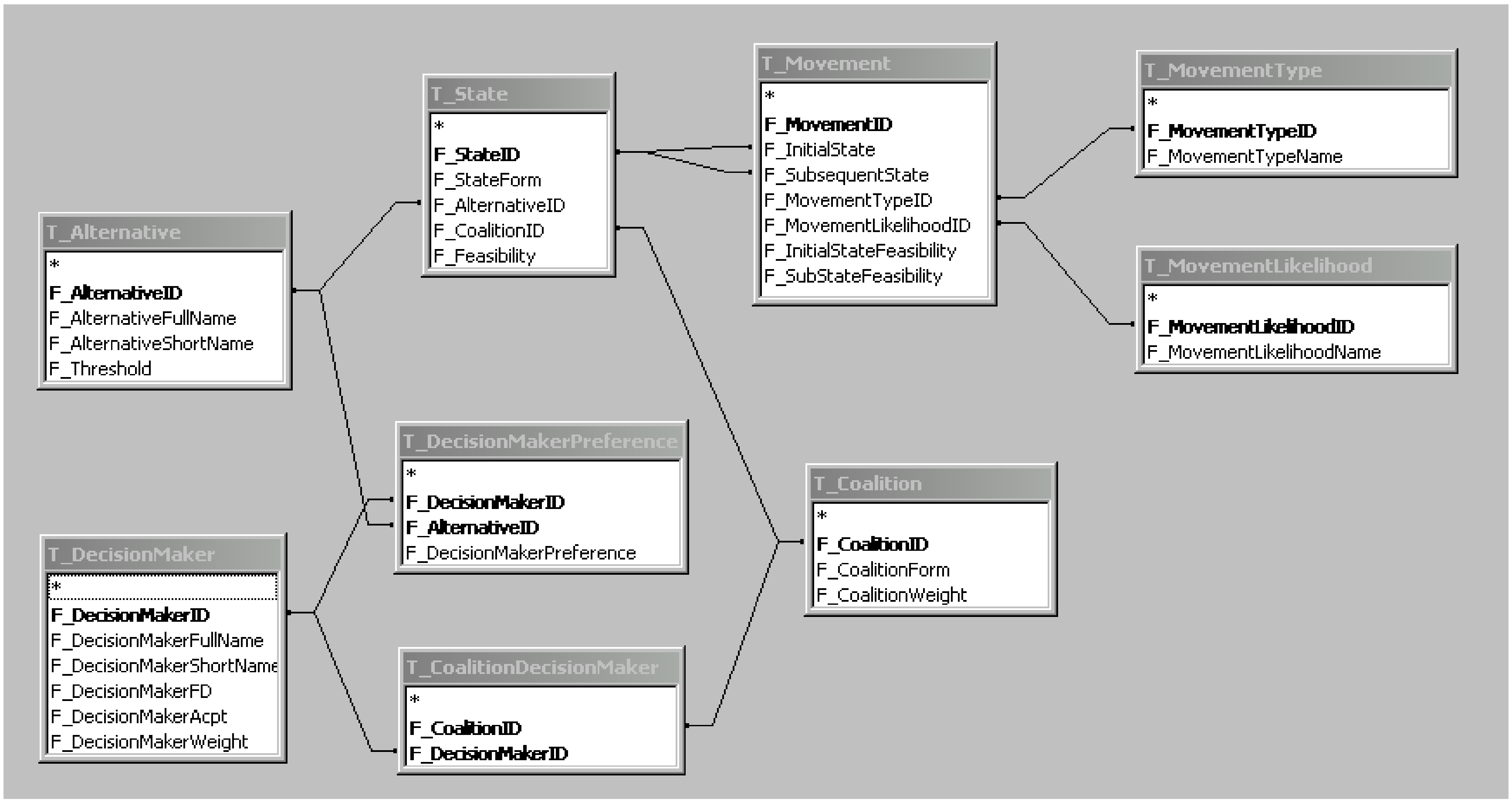

Figure 4.6 - Data Model Diagram for the proposed NSS (Microsoft Access Screen)

4.3 Implementation

Figure 4.7 suggests a general application procedure for the proposed Negotiation Support System for the modeling and analysis of multilateral negotiations.

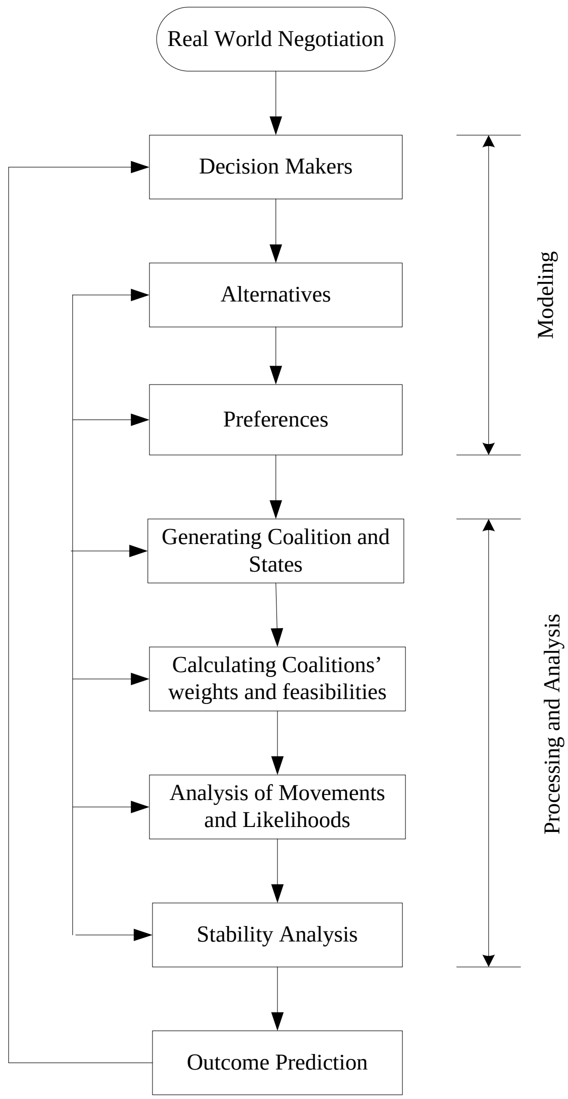

Figure 4.7 - Applying the proposed Negotiation Support Systems (adapted from Figure 1.3.1. Fang, et al., 1993)

Now we show some of the forms which have been designed as part of the interface of the proposed NSS. The input data of each negotiation are entered through the Basic Data menu of the system. For example, Figure 4.8 shows how the specifications of Decision Maker 1 (in Example 1 of Chapter 3) are entered through Decision Maker form.

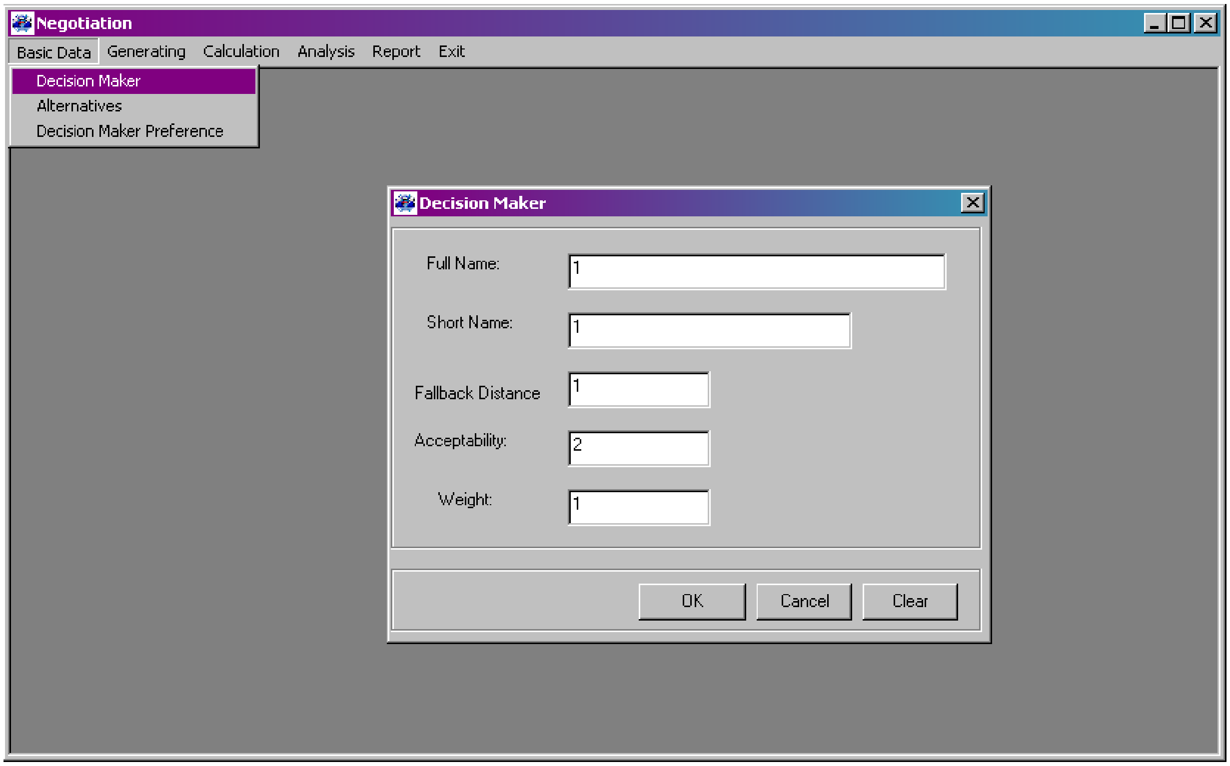

Figure 4.8 – Specifications of a Decision Maker as input data

A list of the submenus of each menu is provided in Table 4.1.

Table 4.1: Specifications of menus of the proposed NSS

Menu	Submenu	Explanation
Basic Data	Decision Maker	Enter the specifications of Decision Makers
	Alternative	Enter the specifications of Alternatives
	Decision Maker Preferences	Enter the preferences of Decision Makers over all alternatives
Generating	Coalition	Generates all possible coalitions
	State	Generates all possible states
	Movement	Generates a from/to matrix of all states
Calculation	Coalition Weight	Calculates the weights of all potential coalitions
	State Feasibility	Determines the feasibility or infeasibility of all states
Analysis	Movements	Analyzes all possible movements from initial states to subsequent ones
Report	Movement	Presents the final results
Exit	--------	Exits from the program

Figure 4.9 shows how the specifications of Alternative A (in Example 1 of Chapter 3) are entered through Alternatives form.

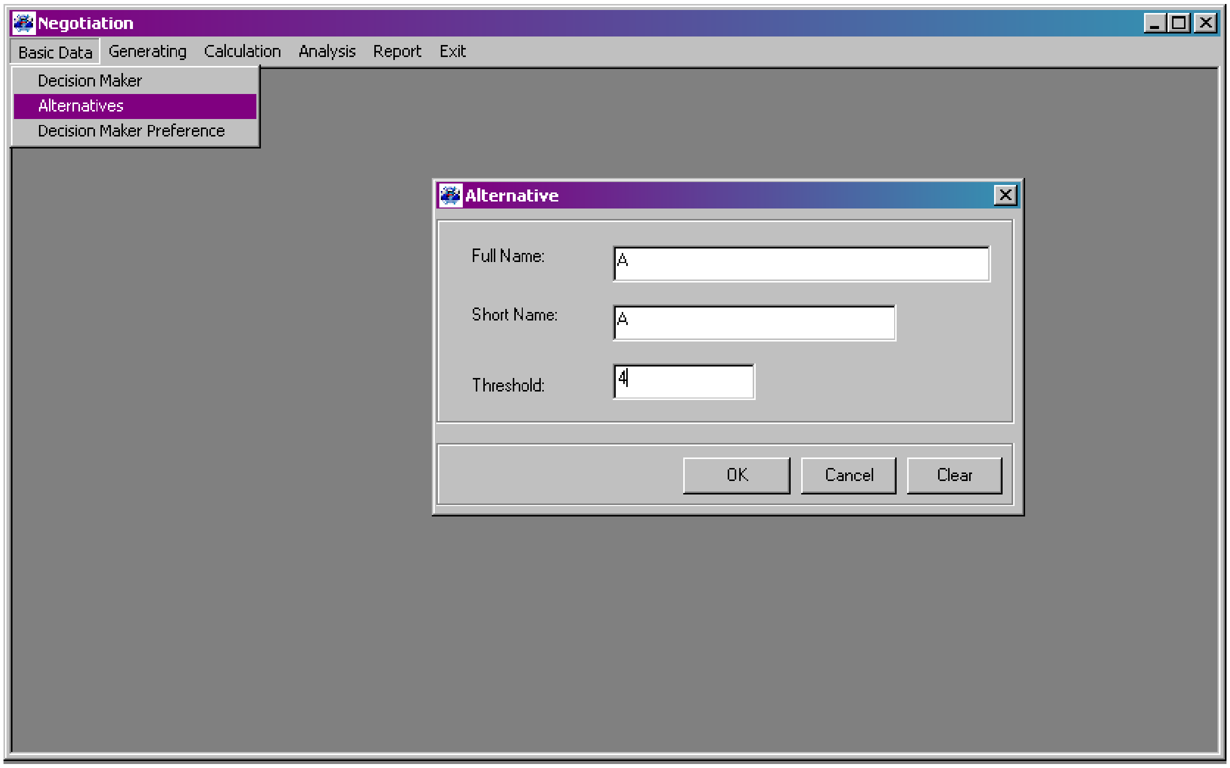

Figure 4.9 – Specifications of an Alternative as input data

Decision Maker Preferences is the last submenu of Basic Data. The user selects one decision maker through the Decision Maker FullName ComboBox and assigns one alternative through the Alternative FullName ComboBox. Then, he or she enters the Preference rank of the selected decision maker for the specified alternative. Figure 4.10 shows that alternative A is the most preferred alternative for Decision Maker 1, i.e., DM 1 gives alternative A preference ranking 1.

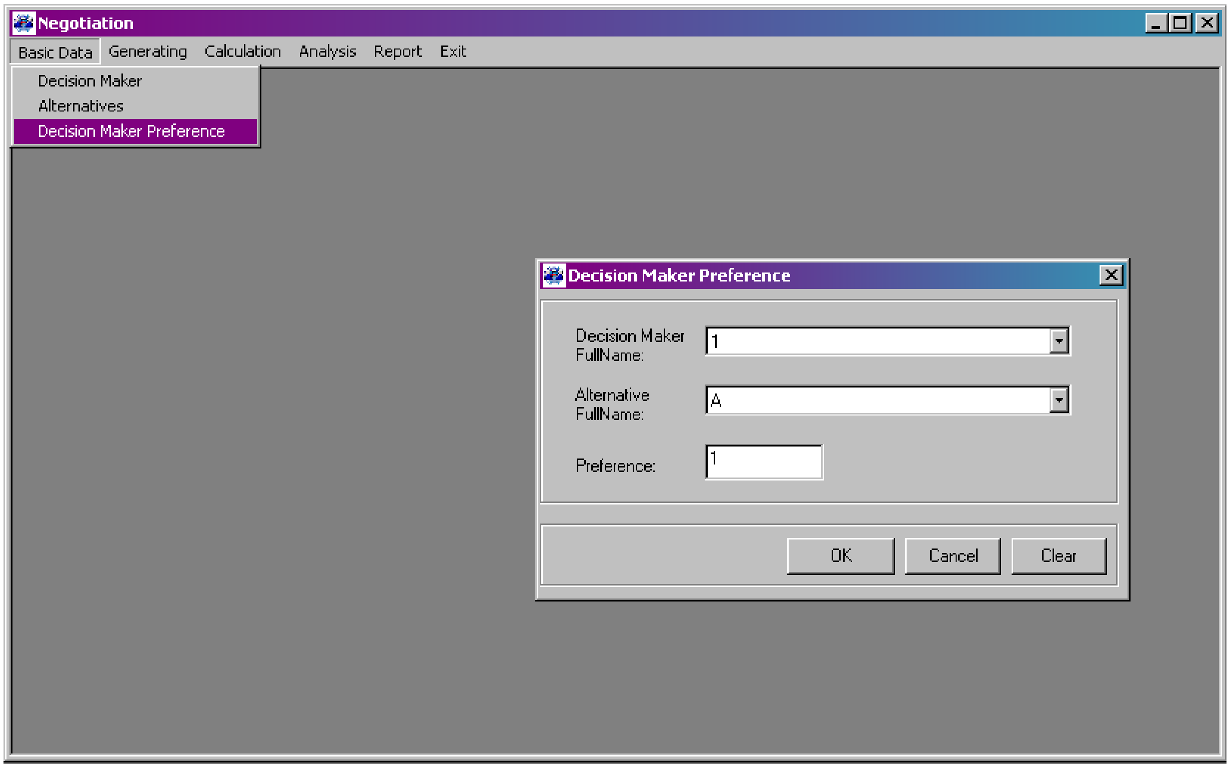

Figure 4.10 – Decision Maker's preference for an alternative as input data

The second main menu of the system is Generating. When this menu is selected, all potential coalitions and states of the negotiation are constructed, based on the input data already entered. In addition, a structure for potential movements from the initial to the subsequent states is constructed by running Movement, the last submenu of Model Generation. The first submenu of the Calculation menu, called Coalition Weight, calculates the weights of all potential coalitions by summing the weights of all decision makers in the coalition. When State Feasibility, the second submenu of the Calculation menu, is selected, the feasibility or infeasibility of all states is determined. State feasibility is determined by a comparison between the coalition's weight in a given state and the threshold of the alternative supported by the coalition. (See Ch.3)

To analyze all possible movements from initial to subsequent states, we select the analysis menu. As soon as we select this menu, a form illustrating the analysis processes appears. This form shows which parts of the process are complete and which parts are not. The process starts with the identification of preferential improvements, and then their associated likelihoods.

Then it investigates all agglomeration movements and their likelihoods and then repeats the calculations for Disloyalty moves. When all strategic disimprovements have been identified and their likelihood determined, the process is complete and we can run the Report menu. Figure 4.11 indicates that the Movement analysis is in progress.

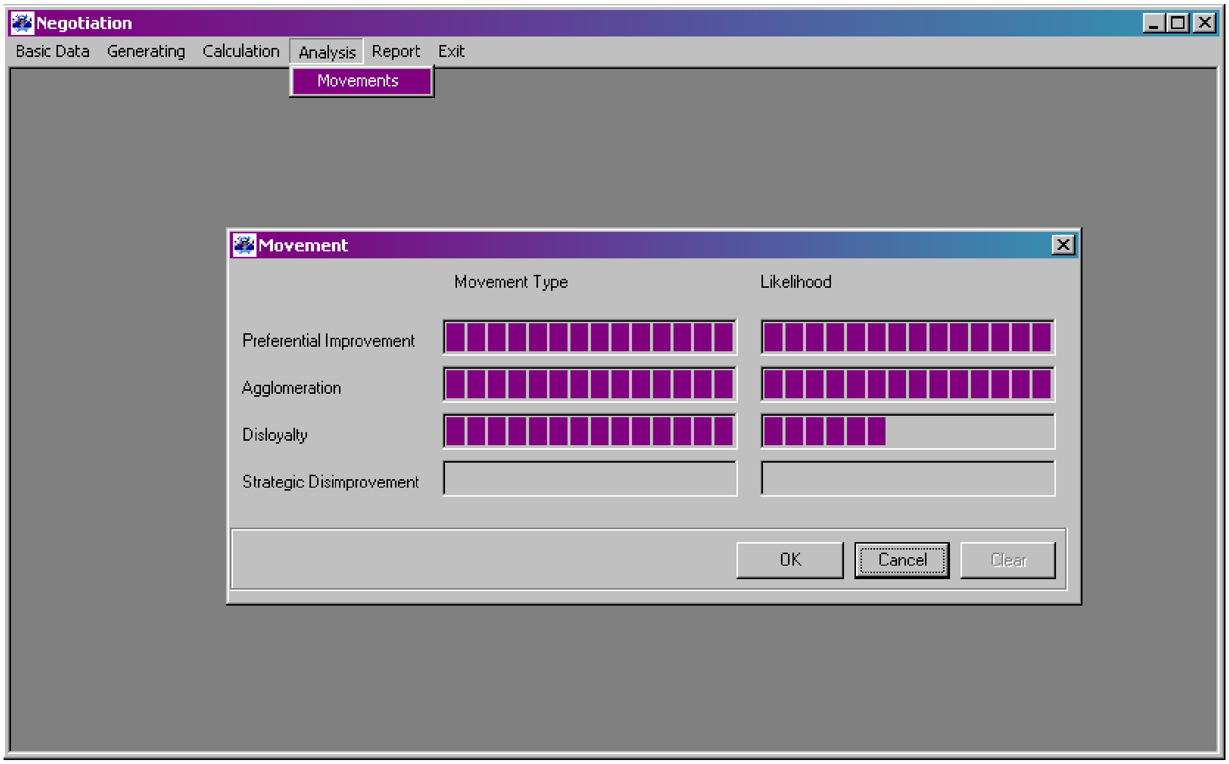

Figure 4.11 – Analysis of Movements and Likelihoods

The Report form presents the final results. This report is a List-View object in Visual Basic. All movements from initial states to subsequent states, in addition to their associated likelihoods, are clearly illustrated. All stable states are distinguished by a check mark (Left column). Feasible stable states are shown distinctively in red colour and bold. Figure 4.12 demonstrates that the state $(A,\{1\})$ is a stable but infeasible state. It also shows a possible preferential improvement from $(B,\{1\})$ to $(A,\{1\})$ and a likely one from $(D,\{1\})$ to $(A,\{1\})$. This picture shows part of the stability analysis which was carried out for Example 1 in the chapter 3.

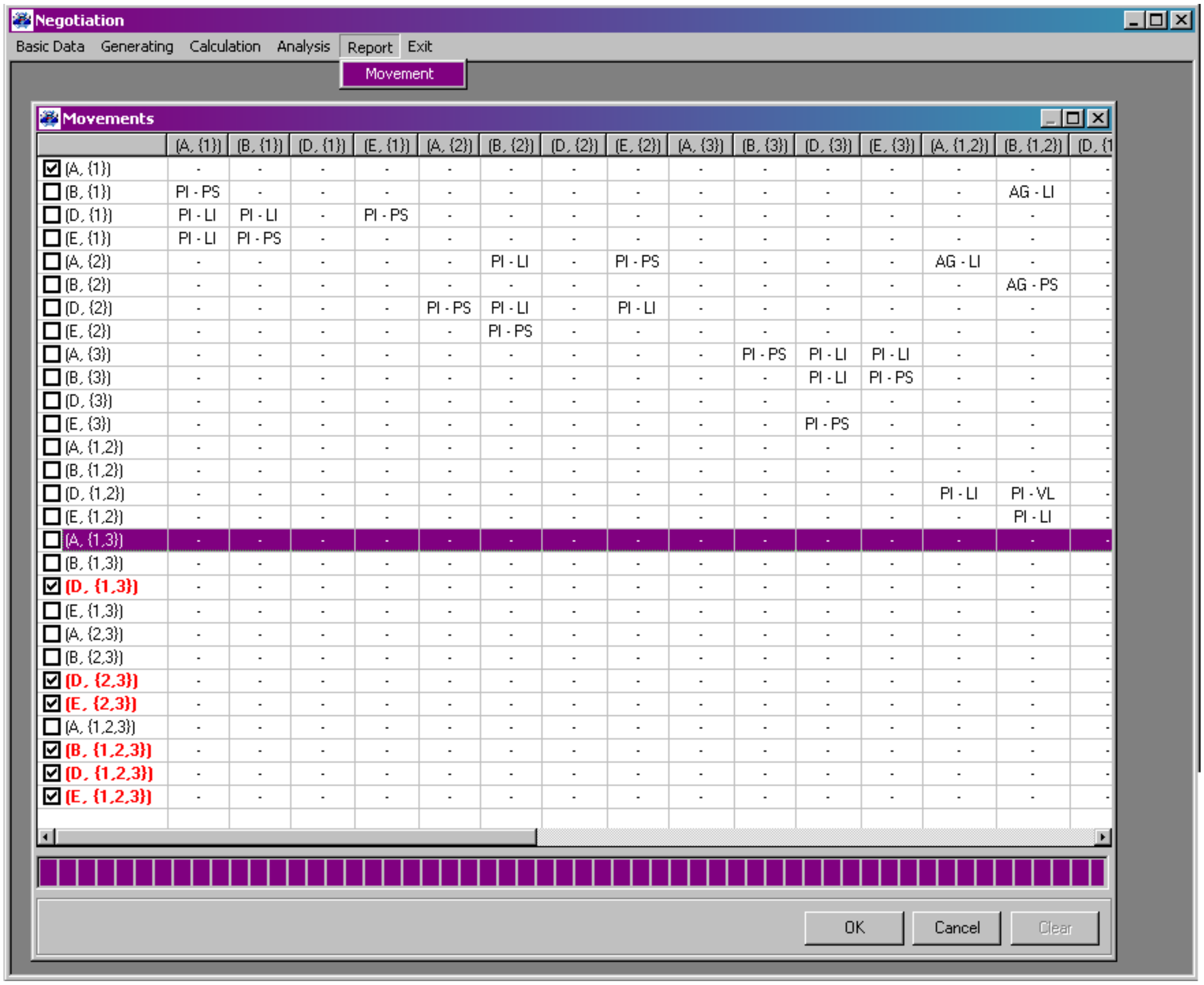

Figure 4.12 – Results of Stability Analysis

4.4 Summary

The design and implementation of a practical Negotiation Support System is briefly explained in this chapter. This Negotiation Support System has been implemented in Microsoft Access using Microsoft Visual Basic, based on the conceptual model for multilateral negotiations proposed in Chapter 3. Two real-world multilateral negotiations will be modeled and analyzed in the following chapters using the proposed methodology and NSS.

Chapter 5

Case Study 1 – Modeling the Caspian Sea Negotiations

5.1 Power in Negotiations

In this chapter, the methodology proposed in the previous chapter will be used to model and analyse multilateral negotiations over the legal status of the Caspian Sea. The most challenging step in modeling the Caspian Sea negotiations is to estimate the DMs' weights.

In some multilateral negotiations, the weights of DMs and the thresholds for potential agreements are clear and prespecified. The following are some examples:

- Decision mechanism of the Security Council of the United Nations.
- Voting system of the European Union.

A negotiation in the US Congress to approve a proposed bill could also be considered another example of multilateral negotiations in which the weights of DMs and the thresholds of agreement are clear, if each party is treated as one DM and the number of senators or representatives of that party is its weight. Of course, this model assumes that members of a party vote identically. In these examples, DMs' weights reflect their level of legitimacy in the voting system. Modeling is easier than when the weights of the DMs are not clearly stipulated.

To model multilateral negotiations like those over the Caspian Sea, DMs' weights must be determined based on their capabilities in the negotiation process. In practice, the powers of the DMs must be estimated quantitatively by the analyst. In these cases, the fundamental issue is the notion of power itself: What is it that enables one party to gain something from another in a negotiation?

Power is a basic concept in both physics and political science. To the physicist, power has a precise definition; to the political scientist, it is vague. At the same time, it is hard to go very deep into an analysis of negotiations without invoking the concept of power. The natural science definition of power faces many conceptual problems when it is imported into the social sciences. In physics, power is defined simply as work done divided by the time taken to accomplish it. Time has a standard measurement and work is defined by the force, which is required to move an object, and the distance.

Since the early 1930s, social scientists have had a good working definition of power as *the ability of one party to move another party in an intended direction*. Originally formulated by Tawney (1931/1952:159), this idea was widely adopted in the 1950s – by decision theorists such as Herbert Simon (1953), political scientists like Robert Dahl (1957), and social psychologists such as John Thibaut and Harold Kelley (1959). It is obvious that "move" refers here not to physical displacement but to change in position, in thought and action. A variant conceptualization considers power as *the value added to a particular outcome* (Schelling 1960; Zartman 1974). One agent exercises power in its relationship with another when its actions can negatively or positively alter the value of a particular action with respect to reaching to target. This approach retains the notion of power as a bilateral relation, and provides a common dimension on which to compare and aggregate different expressions of power. The stronger party is the one that can add (or subtract) more value to (or from) the other's outcome. One way of categorizing the actions that produce movement is as pressure (negative), inducement (positive), and resistance (negative or positive response). Thus, contingent moves can be divided into threats and warnings (negative) and promises (positive).

There are two main difficulties in measurement of power. First, resources come in many shapes and sizes, making them difficult to aggregate them within a single measure. Second, resources also come shapelessly, for example in leadership or moral rights, obligations, or commitments. Therefore, it is very difficult to measure precisely the power of decision makers in negotiations.

An understanding of the nature and significance of power asymmetry is obviously important for a better understanding of the strategic problems represented by the real-world conflicts. Hierarchical power involves the ability of a decision maker to choose a strategy in the knowledge of the opponent's choice. A flexible concept of hierarchical power has been developed within the framework of non-cooperative game theory to extend the systems-theory approach to the analysis of strategic interactions among decision makers having asymmetric roles (De *et al.*, 1990). Hierarchical power, a model for power asymmetry, has been also used in conjunction with other principles of personnel management to analyze the behavior of professionals during negotiations in an organization (De *et al.*, 1994).

Stoll and Ward (1989) attempted to measure nations' power quantitatively. They refer to some multivariate indexes representing the power of states (nations). A straightforward linear index was suggested by Alcock and Newcombe (1970), who used a regression equation to measure relative power of nations. They saw relative power as dependent on three factors: gross national product per capita, population, and population density. They came up with the relation:

Relative power = - 16.1 + 0.69 population + 0.49 GNP/cap + 0.08 area/cap.

While this equation is not quite appropriate for the negotiation over the Caspian Sea, it can be used as a starting point.

5.2 Calibrating the Model; Decision Makers' Weights

In the negotiation over the legal status of the Caspian Sea, the weights of the decision makers and the thresholds for agreement are not prespecified. As explained in previous sections, the countries around the Caspian Sea are not unanimous over whether it is a sea, a lake, or another kind of body of water; agreement on the sea or lake question would permit the legal status to be resolved based on international law. We proceed to estimate the power of the countries involved in these negotiations by applying a Multiple Criteria Decision Analysis (MCDA) model. It should be emphasised that this is an estimation problem and that precise measurement of the nations' powers is not possible because some criteria like diplomatic efforts or negotiators' tactical skills are not quantified and therefore cannot be easily measured.

5.2.1 The criteria

Table 5-1 lists all criteria that are considered to be important determinants of countries' capabilities in Caspian Sea negotiations. For each criterion, associated indicators are also given. Later we discuss how to combine indicator values to obtain weights for the countries.

Table 5.1: criteria and indicators applied to estimate the weights of the countries

Criteria	Number	Indicator
Economic Independence and Self sufficiency	1-1	GNI/capita
	1-2	Net trade / GDP
	1-3	GDP/ Claimed Caspian Sea oil and natural gas
Military status of the country	2-1	Yearly Military Expenditures
	2-2	Military Expenditures/ GDP
	2-3	Active troops/ Population
	2-4	Nuclear power status
US Support	3-1	US Financial support
	3-2	US Political support
Political Influence and Structure	4-1	The Territory of Political Influence
	4-2	Democracy Level

1) Economic Independence and Self sufficiency:

Indicators:

1-1) GNI/capita

The higher the GNI/capita, the wealthier the country. Gross National Income comprises the total value of goods and services produced within a country (i.e. its Gross Domestic Product), together with its income received from other countries (notably interest and dividends), less similar payments made to other countries. For example, if a British-owned company operating in the US sends some of its profits back to UK, the UK's GNI is enhanced, and the amount will not count toward US GNI (Yahoo! Canada Answers, 2007). In other words, Gross

National Income is the value of all income earned by residents of an economy whether it is earned within or outside of the national boundary (Definitions of GNI on the Web, 2007). Table 5.2 shows the GNI/capita for the countries and the scaled values out of 10.

Table 5.2: GNI/capita

Country	**GNI per capita (US $)**	**Out of 10**
Azerbaijan	1,240	2.78
Kazakhstan	2,930	6.57
Iran	2,770	6.21
Russia	4,460	10
Turkmenistan	1,340	3

Source: http://news.bbc.co.uk/2/hi/europe/country_profiles/1235976.stm (Sep. 9, 07)
The World Bank - Data for the year 2006.

1-2) Net trade / GDP = $\frac{\text{Total exports - Total imports}}{\text{GDP}}$

The higher Net trade /GDP, the greater the Economic Independence. The gross domestic product (GDP) is a primary indicator of the health of a country's economy. It represents the total value of all goods and services produced within a country over a specific time period. It is usually thought of as the size of the economy. (Investopedia, 2007) Table 5.3 illustrates the Net trade / GDP for the countries and the scaled values out of 10.

Table 5.3: Net trade / GDP

Country	**Net trade** (millions of USD) (2005)	**GDP** (millions of USD)	**Net trade as % of GDP** →	**Square Root**	**Out of 10**
Azerbaijan	136	20,122	0.68	0.82	1.57
Kazakhstan	10,497	77,237	13.6	3.69	7.07
Iran	21,337	222,889	9.6	3.1	5.94
Russia	142,667	986,940	14.5	3.81	7.3
Turkmenistan	2,854	10,496	27.2	5.22	10

Source: Trade Competitiveness Map
http://www.intracen.org/appli1/TradeCom/TP_EP_CI.aspx?RP=031&YR=2005 (Sep. 9, 2007)
List of countries by GDP, List by the World Bank, 2006
http://en.wikipedia.org/wiki/List_of_countries_by_GDP_%28nominal%29 (Sep. 14, 2007)

In Table 5.3, the square root function is used to capture the non-linearity of the criteria. This transformation reflects the concavity of the function $y = \sqrt{x}$. For instance, the difference between 2 and 3 in the Net trade as % of GDP column is more significant than the difference between 20 and 21. Hence, we use the square root function to give a rough representation of the non-linear nature of the criterion.

1-3) GDP/ Claimed Caspian Sea oil and natural gas

The higher the ratio of GDP/Claimed Caspian Sea oil and natural gas, the more willing the country to wait for benefits from the Caspian Sea. In other words, countries for which the relative benefit of the oil and natural gas of the Caspian Sea is very high need an agreement over its legal status to extract these resources as soon as possible. On the other hand, countries that possess other resources are not so dependent on these sources and can wait to achieve more preferable alternatives in the negotiations. The information in the third column (Claimed oil and natural gas) of Table 5.4 is from the bankruptcy procedure section of Chapter 2.

Table 5.4: GDP/ Claimed Caspian Sea oil and natural gas

Country	**GDP** (millions of USD)	**Claimed Oil and Natural Gas** (billion$)	**GDP/ Claimed Caspian Sea Oil and Natural Gas**	**Square Root**	**Out of 10**
Azerbaijan	20,122	2580	7.8	2.79	1.46
Kazakhstan	77,237	5968	12.94	3.6	1.88
Iran	222,889	2702	82.49	9.08	4.75
Russia	986,940	2702	365.27	19.11	10
Turkmenistan	10,496	3838	2.73	1.65	0.86

2) Military status of the country:

The following criteria help us to estimate the military capability of the countries.

Indicators:

2-1) Yearly Military Expenditures

This statistic reflects the level of military buildup and army modernization for a countriy. Table 5.5 shows the Yearly Military Expenditures of the countries around the Caspian Sea and provides a non-linear ranking, for reasons similar to those discussed above.

Table 5.5: Yearly Military Expenditures

Country	**Military Expenditures** (millions of USD)	**Square Root**	**Out of 10**
Azerbaijan	1100	33.17	1.84
Kazakhstan	221.8	14.89	0.83
Iran	6,300	79.37	4.41
Russia	32,400	180	10
Turkmenistan	90	9.49	0.53

Source: http://en.wikipedia.org/wiki/List_of_countries_by_military_expenditures (Sep. 8, 2007)

2-2) Military Expenditures/ GDP

This ratio indicates how much priority each country places on military expenditure. In other words, it represents the percentage of gross domestic product of a country that is spent for military purposes. Again, it is scaled non-linearly using the square root function.

Table 5.6: Military Expenditures/ GDP

Country	**Military Expenditures** (millions of USD)	**GDP** (millions of USD)	**Military Expenditures as % of GDP**	**Square Root**	**Out of 10**
Azerbaijan	1100	20,122	5.5	2.35	10
Kazakhstan	221.8	77,237	0.29	0.54	2.29
Iran	6,300	222,889	2.8	1.67	7.12
Russia	32,400	986,940	3.28	1.81	7.71
Turkmenistan	90	10,496	0.86	0.93	3.95

2-3) Active troops/ Population

This ratio indicates how much priority each country places on having active troops. Table 5.7 measures aactive troops per capita for the five Caspian Sea countries.

Table 5.7: Active troops/ Population

Country	Active troops (thousands)	Population (thousands)	Active troops/ Population	Out of 10
Azerbaijan	126	8400	1.5	10
Kazakhstan	65	15400	0.422	2.81
Iran	545	68500	0.796	5.31
Russia	1200	143800	0.834	5.56
Turkmenistan	26	5000	0.52	3.47

Sources: http://en.wikipedia.org/wiki/List_of_countries_by_size_of_armed_forces (Sep. 8, 07)
http://news.bbc.co.uk/2/hi/europe/country_profiles/1235976.stm (Sep. 8, 2007)

A positive correlation is to be expected between the results of the two previous indicators, Military Expenditures/ GDP and Active troops/ Population since both indicators evaluate to what extent the countries are serious in their military development. Hence, the average of the results in the last columns of Tables 5.6 and 5.7 can be used as a single indicator of military importance. Alternatively, each of these two indicators can be assigned lower weight in the overall evaluation.

2-4) Nuclear power status

Nuclear power is usually considered as a great symbol of military power of a country. It might affect the position of a country in negotiations. Table 5.8 shows the nuclear power status of the five Caspian Sea countries.

Table 5.8: Nuclear power status

Country	Nuclear power status	Out of 10
Azerbaijan	---------	0
Kazakhstan	formerly possessing state	3
Iran	has uranium enrichment capability	3
Russia	nuclear weapons state	10
Turkmenistan	---------	0

Sources:

http://en.wikipedia.org/wiki/List_of_states_with_nuclear_weapons#Former_Soviet_countries

http://www.fas.org/nuke/guide/kazakhstan/index.html (*Kazakhstan Special Weapons*)

The fall of the USSR left several former Soviet-bloc countries in possession of nuclear weapons. Kazakhstan inherited 1,400 nuclear weapons from the Soviet Union, but transferred them all to Russia by 1995. Although Kazakhstan has signed the Nuclear Non-Proliferation Treaty, this country must be taken into account as a state that is potentially capable to develop nuclear weapons. Iran signed the Nuclear Non-Proliferation Treaty and says its interest in nuclear technology, including enrichment, is for civilian purposes only (a right guaranteed under the treaty), but the Security Council of United Nations suspects that this is a cover for a nuclear weapons program. In fact, Iran does possesses Uranum enrichment capability which is considered a key stage in developing nuclear weapons.

3) US Support

The Caspian Sea region is economically and strategically important for all international powers. But more than EU or China, the US has the greatest interests and ambitions in this region. Because of its wealth, strength, and influence, the actions of the US affect other nations. One notable area is US foreign aid, which in reality is US financial support for its allied countries. Then funds support US geo-strategic interests and aim to achieve specific US foreign policy goals in countries of high priority from a strategic standpoint. For example, Israel receives huge financial support from the US because it is the most important ally of the US in the Middle East.

Indicators:

3-1) US Financial support

The higher amount of US financial support for a country, the higher the US interest in that country. Such a country can rely on US political support.

Table 5.9: US Financial Support

Country	**2004**	**2005**	**2006**	**Total** (millions of USD)	**Square Root**	**Out of 10**
Azerbaijan	38.782	37.355	35	111.137	10.54	6.83
Kazakhstan	33.342	26.690	26	86.032	9.28	6.01
Iran	0	0	0	0	0	0
Russia	99.35	88	51	238.350	15.44	10
Turkmenistan	5.7	6.505	5.5	17.705	4.21	2.73

Source: http://www.usaid.gov/policy/budget/cbj2006/ee/kz.html (Oct. 25, 07)

3-2) US Political support

As discussed in the background section of the conflict, the newly independent countries believe that condominium regime causes political and economic domination of Russia and Iran over the Caspian Sea. Therefore, they are deeply interested in division of the Caspian Sea. This conform the US interests because the US plans to stop the hegemony of Iran and Russia in the region. That is why western-oriented political parties are supported by US to obtain the power in the newly independent countries. Table 5.10 represents to what extent the five Caspian Sea countries are politically supported by US.

Table 5.10: US Political Support

Country	**US Attitude**	**Out of 10**
Azerbaijan	+ +	10
Kazakhstan	+	8
Iran	-	0
Russia	0	2
Turkmenistan	+	8

The symbol + + in Table 5.10 means very great, + means positive, 0 means neutral and – indicates a negative attitude. All newly independent countries around the Caspian Sea are supported politically by US, but Azerbaijan possesses a greater strategic importance to the US. This country is located between Iran and Russia, and is a bridge between Asia and Europe. In spite of some mutual cooperation between the US and Russia, the US still considers Russia as one of its greatest opponents. That is why we indicate a politically neutral attitude to Russia, although the US financial support paid to Russia during the years 2004-2006 is the highest among those paid to the five Caspian Sea countries.

4) Political Influence and Structure

A higher internal stability a wider territory of political influence can strengthen the position of a country in regional negotiations.

Indicators:

4-1) The Territory of Political Influence

This indicator determines whether a country is a Local, Regional or an International power. In Table 5.11, the scores 0, 3, and 10 are assigned to a Local, Regional or an International power, respectively.

Table 5.11: The Territory of Political Influence

Country	**Political Influence**	**Out of 10**
Azerbaijan	Local	0
Kazakhstan	Local	0
Iran	Regional	3
Russia	International	10
Turkmenistan	Local	0

4-2) Democracy Level

Democracy leads to the stability of a country in the long term. Table 5.12 shows to what extent the countries around the Caspian Sea are democratic according to the Economist Intelligence Unit democracy index 2006. The subcriteria are listed in the Table and the scores range from 0 to 12.

Table 5.12: Economist Intelligence Unit democracy index 2006

Country	Electoral Process and Pluralism	Functioning of Government	Political Participation	Political Culture	Civil Liberties	Overall Score	Out of 10
Azerbaijan	3.08	0.79	3.33	3.75	5.59	3.31	6.59
Kazakhstan	2.67	2.14	3.33	4.38	5.59	3.62	7.2
Iran	0.08	3.57	3.89	5.63	1.47	2.93	5.84
Russia	7.00	3.21	5.56	3.75	5.59	5.02	10
Turkmenistan	0.00	0.79	2.78	5.00	0.59	1.83	3.65

Source: (Kekic 2007)
http://www.economist.com/media/pdf/DEMOCRACY_INDEX_2007_v3.pdf (Oct. 31, 2007)

We now summarize all results from Table 5.2 to Table 5.12 in Table 5.13 to evaluate the weight of each country involved in the Caspian Sea negotiations.

Table 5.13: Summary of Scores

Country/Criteria	1-1	1-2	1-3	2-1	2-2	2-3	2-4	3-1	3-2	4-1	4-2
Azerbaijan	2.78	1.57	1.46	1.84	10	10	0	6.83	10	0	6.59
Kazakhstan	6.57	7.07	1.88	0.83	2.29	2.81	3	6.01	8	0	7.2
Iran	6.21	5.94	4.75	4.41	7.12	5.31	3	0	0	3	5.84
Russia	10	7.3	10	10	7.71	5.56	10	10	2	10	10
Turkmenistan	3	10	0.86	0.53	3.95	3.47	0	2.73	8	0	3.65

5.2.2 Using Data Envelopment Analysis to determine aggregate weights

Data Envelopment Analysis (DEA) is an increasingly popular management decision tool initially proposed by Charnes et al. (1978). It is a linear programming based technique originally designed to measure the relative performance of a number of producers or decision making units, where the presence of multiple inputs and outputs makes comparisons difficult. During the last twenty years, a significant amount of research has focused on DEA for both theoretical extensions and practical applications. For example, Cook and Kress (1994) discussed relationships between DEA and MCDA and proposed a DEA-based MCDA method to handle both cardinal and ordinal criteria.

To evaluate the weights of the decision makers (*N-weights*) in the negotiations over the Caspian Sea, we must determine the importance of each criterion. One method is to apply the DEA method to find the most favourable set of relative importance of different criteria (*C-weights*) for each country.

If a criterion affects the position of a country in the Caspian Sea negotiations very significantly, then we try to assign a higher weight (*C-weight*) to that criterion. If a criterion affects the position of a country in the negotiation only marginally, we assign a lower weight to that criterion. It is often difficult to find a set of generally accepted *C-weights* to aggregate the indices properly, which is a good reason to apply the DEA method. Based on the DEA concept, the C-weight of a criterion for a specific country could be different from the weight of that criterion for another country. However, the comparison is conducted in a fair manner by permitting a country to maximize its possibility of obtaining the best aggregate evaluation result (the highest *N-weight*). For example, we now maximize the total weight of Azerbaijan (w_A) using the following linear program. Table 5-14 shows the *C-weight* variables associated with the described criteria.

Table 5.14: The associated *C-weight* variables

Criteria	1-1	1-2	1-3	2-1	2-2	2-3	2-4	3-1	3-2	4-1	4-2
C-weight	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11

```
MAX
```

W_A=2.78*w1+1.57*w2+1.46*w3+1.84*w4+10*w5+10*w6+0*w7+6.83*w8+10*w9+0*w10+6.59*w11;

We now summarize the assumptions and then show how these assumptions are implemented by the constraints of the linear program. Suppose that:

- The N-weights of the countries are scaled out of 10. Hence, no *N-weight* can exceed 10. (Inequations 1 to 5)
- The sum of the all *C-weights* for each country is equal to 1. (Equation 6)
- In addition, no *C-weight* could be selected as zero. In other words, *N-weight* of a country is affected by all described criteria. (Inequations 7 to 17)
- The criteria 2-1 and 4-1 (the Yearly Military Expenditures and the Territory of Political Influence), associated with w4 and w10, are equally the most important criteria. (Equation 18 and Inequations 19 to 27)
- The criterion 1-1 measuring GNI/capita is considered as the third important criterion. (Inequations 28 to 35)
- After the mentioned priorities, the criteria 1-3, 2-4 and 3-1 are equally the most important criteria that affect the N-weight of a country. (Equation 36 and 37 and Inequations 38 to 42)

```
St:

2.78*w1+1.57*w2+1.46*w3+1.84*w4+10*w5+10*w6+0*w7+6.83*w8+10*w9+0*w10+
6.59*w11<=10;                                                         (1)

6.57*w1+7.07*w2+1.88*w3+0.83*w4+2.29*w5+2.81*w6+3*w7+6.01*w8+8*w9+0*w10+
7.2*w11<=10;                                                          (2)

6.21*w1+5.94*w2+4.75*w3+4.41*w4+7.12*w5+5.31*w6+3*w7+0*w8+0*w9+3*w10+
5.84*w11<=10;                                                         (3)

10*w1+7.3*w2+10*w3+10*w4+7.71*w5+5.56*w6+10*w7+10*w8+2*w9+10*w10+10*w11<=10;
                                                                      (4)

3*w1+10*w2+0.86*w3+0.53*w4+3.95*w5+3.47*w6+0*w7+2.73*w8+8*w9+0*w10+3.65*w11
<=10;                                                                 (5)
```

```
w1+w2+w3+w4+w5+w6+w7+w8+w9+w10+w11=1;                    (6)


w1>0.001;                                                (7)
w2>0.001;                                                (8)
w3>0.001;                                                (9)
w4>0.001;                                                (10)
w5>0.001;                                                (11)
w6>0.001;                                                (12)
w7>0.001;                                                (13)
w8>0.001;                                                (14)
w9>0.001;                                                (15)
w10>0.001;                                               (16)
w11>0.001;                                               (17)


w4=w10;                                                  (18)

w4-w1>=0.001;                                            (19)
w4-w2>=0.001;                                            (20)
w4-w3>=0.001;                                            (21)
w4-w5>=0.001;                                            (22)
w4-w6>=0.001;                                            (23)
w4-w7>=0.001;                                            (24)
w4-w8>=0.001;                                            (25)
w4-w9>=0.001;                                            (26)
w4-w11>=0.001;                                           (27)



w1-w2>=0.001;                                            (28)
w1-w3>=0.001;                                            (29)
w1-w5>=0.001;                                            (30)
w1-w6>=0.001;                                            (31)
w1-w7>=0.001;                                            (32)
w1-w8>=0.001;                                            (33)
w1-w9>=0.001;                                            (34)
w1-w11>=0.001;                                           (35)



w3=w7;                                                   (36)

w3=w8;                                                   (37)

w3-w2>=0.001;                                            (38)
w3-w5>=0.001;                                            (39)
w3-w6>=0.001;                                            (40)
w3-w9>=0.001;                                            (41)
w3-w11>=0.001;                                           (42)

END
```

Solving the above linear program using the software LINGO, the value of objective function is w_A = 4.911540. Similarly, we maximize the N-weights of other countries by solving other linear programs with identical constraints and different objective functions. For example, the following objective function is applied to maximize the N-weight of Kazakhstan:

w_K =6.57*w1+7.07*w2+1.88*w3+0.83*w4+2.29*w5+2.81*w6+3*w7+6.01*w8+8*w9+0*w10+7.2*w11

If we substitute the above objective function with the previous one (which was for Azerbaijan) and keep the previous constrains we determine w_K , N-weight of Kazakhstan to be w_K = 4.479700. Table 5.15 shows the N-weights of the countries based on DEA system. Each number in this table is the value of each objective function (N-weights) as the output data of the appropriate linear program.

Table 5.15: N-weights of the countries as determined by DEA

Country	Overall Performance (Out of 10)
Azerbaijan	4.911540
Kazakhstan	4.479700
Iran	4.545704
Russia	9.982570
Turkmenistan	3.264990

5.3 Applying the Model

As discussed in Chapter 2, there are five ways to resolve the legal status of the Caspian Sea, as follows:

C: Condominium

D_m: Division based on the International Law applying to Seas

D_e: Equal Division: 20% of the sea, and the seabed, to each littoral state

D_s: Division based on Soviet maps

DC: Division of the seabed based on International Law, condominium on the surface

In Chapter 2, it was noted that each state has strict preferences over the five alternatives, based on assessments of their national economic, political and military interests. The states' preferences are as follows:

Azerbaijan **:** $D_s > D_m > DC > D_e > C$

Iran **:** $C > D_e > D_m > DC > D_s$

Kazakhstan **:** $D_s > D_m > DC > C > D_e$

Russia : $C > DC > D_s > D_m > D_e$

Turkmenistan: $D_e > D_s > D_m > DC > C$

Other parameters of the model of the negotiation over the legal status of the Caspian Sea are shown in Table 5-16. The numbers in the Weight coulomb of this Table are the rounded N-weights from Table 5.15. Acceptability and Fallback Distance of the five Caspian Sea states were defined in Chapter 3 and are supposed based on the historical background explained before.

Table 5.16: Negotiation Parameters of the countries

Country	Weight	Acceptability	Fallback Distance
Azerbaijan	4.91	2	1
Iran	4.55	1	1
Kazakhstan	4.48	2	1
Russia	9.98	1	1
Turkmenistan	3.26	3	1

In the Caspian Sea negotiations, there are five decision makers and five alternatives, so the number of the negotiation states is $5 \times (2^5 - 1) = 155$

We know that some bilateral treaties or multilateral agreements among some of the five states have already occurred since the collapse of the USSR. But these agreements may not endure, because the five presidents of the Caspian Sea states agreed, in their joint declaration at the end of the Tehran meeting in October 2007, that the legal regime of the Caspian Sea should be determined unanimously.

5.3.1 Verification of the proposed methodology

In this section, we apply the proposed methodology to verify to what extent the model can predict the observed outcomes of the negotiations over the legal status of the Caspian Sea. For this purpose, we suppose that the threshold for any alternative is equal to 19. (In other words, we let the model consider some non- unanimous agreements as feasible. However, no agreement without Russia's support is considered feasible. All potential states are listed in Table 5.17, which also includes feasibility and stability status of the states when T = 19 for all alternatives. A feasible state is denoted by F and a stable state is indicated by S in this table.

Table 5.17: Results of the negotiation modeling for methodology verification

State ID	State	Feasibility	Stability	State ID	State	Feasibility	Stability
1	$(C,\{A\})$			79	$(D_s,\{A,I,K\})$		
2	$(D_m,\{A\})$			80	$(\text{DC},\{A,I,K\})$		
3	$(D_e,\{A\})$			81	$(C,\{A,I,R\})$	F	S
4	$(D_s,\{A\})$			82	$(D_m,\{A,I,R\})$	F	
5	$(\text{DC},\{A\})$			83	$(D_e,\{A,I,R\})$	F	
6	$(C,\{I\})$			84	$(D_s,\{A,I,R\})$	F	
7	$(D_m,\{I\})$			85	$(\text{DC},\{A,I,R\})$	F	S
8	$(D_e,\{I\})$			86	$(C,\{A,I,T\})$		
9	$(D_s,\{I\})$			87	$(D_m,\{A,I,T\})$		
10	$(\text{DC},\{I\})$			88	$(D_e,\{A,I,T\})$		
11	$(C,\{K\})$			89	$(D_s,\{A,I,T\})$		

12	$(D_m, \{K\})$			90	$(\mathrm{DC}, \{A, I, T\})$		
13	$(D_e, \{K\})$			91	$(C, \{A, K, R\})$	F	
14	$(D_s, \{K\})$			92	$(D_m, \{A, K, R\})$	F	
15	$(\mathrm{DC}, \{K\})$			93	$(D_e, \{A, K, R\})$	F	
16	$(C, \{R\})$			94	$(D_s, \{A, K, R\})$	F	
17	$(D_m, \{R\})$			95	$(\mathrm{DC}, \{A, K, R\})$	F	S
18	$(D_e, \{R\})$			96	$(C, \{A, K, T\})$		
19	$(D_s, \{R\})$			97	$(D_m, \{A, K, T\})$		
20	$(\mathrm{DC}, \{R\})$			98	$(D_e, \{A, K, T\})$		
21	$(C, \{T\})$			99	$(D_s, \{A, K, T\})$		S
22	$(D_m, \{T\})$			100	$(\mathrm{DC}, \{A, K, T\})$		
23	$(D_e, \{T\})$		S	101	$(C, \{A, R, T\})$		
24	$(D_s, \{T\})$			102	$(D_m, \{A, R, T\})$		
25	$(\mathrm{DC}, \{T\})$			103	$(D_e, \{A, R, T\})$		
26	$(C, \{A, I\})$			104	$(D_s, \{A, R, T\})$		
27	$(D_m, \{A, I\})$			105	$(\mathrm{DC}, \{A, R, T\})$		
28	$(D_e, \{A, I\})$			106	$(C, \{I, K, R\})$	F	S
29	$(D_s, \{A, I\})$			107	$(D_m, \{I, K, R\})$	F	
30	$(\mathrm{DC}, \{A, I\})$			108	$(D_e, \{I, K, R\})$	F	
31	$(C, \{A, K\})$			109	$(D_s, \{I, K, R\})$	F	
32	$(D_m, \{A, K\})$			110	$(\mathrm{DC}, \{I, K, R\})$	F	S
33	$(D_e, \{A, K\})$			111	$(C, \{I, K, T\})$		
34	$(D_s, \{A, K\})$			112	$(D_m, \{I, K, T\})$		
35	$(\mathrm{DC}, \{A, K\})$			113	$(D_e, \{I, K, T\})$		
36	$(C, \{A, R\})$			114	$(D_s, \{I, K, T\})$		
37	$(D_m, \{A, R\})$			115	$(\mathrm{DC}, \{I, K, T\})$		

38	$(D_e,\{A,R\})$			116	$(C,\{I,R,T\})$		S
39	$(D_s,\{A,R\})$			117	$(D_m,\{I,R,T\})$		
40	$(\mathrm{DC},\{A,R\})$			118	$(D_e,\{I,R,T\})$		
41	$(C,\{A,T\})$			119	$(D_s,\{I,R,T\})$		
42	$(D_m,\{A,T\})$			120	$(\mathrm{DC},\{I,R,T\})$		
43	$(D_e,\{A,T\})$			121	$(C,\{K,R,T\})$		
44	$(D_s,\{A,T\})$			122	$(D_m,\{K,R,T\})$		
45	$(\mathrm{DC},\{A,T\})$			123	$(D_e,\{K,R,T\})$		
46	$(C,\{I,K\})$			124	$(D_s,\{K,R,T\})$		
47	$(D_m,\{I,K\})$			125	$(\mathrm{DC},\{K,R,T\})$		
48	$(D_e,\{I,K\})$			126	$(C,\{A,I,K,R\})$	F	S
49	$(D_s,\{I,K\})$			127	$(D_m,\{A,I,K,R\})$	F	
50	$(\mathrm{DC},\{I,K\})$			128	$(D_e,\{A,I,K,R\})$	F	
51	$(C,\{I,R\})$		S	129	$(D_s,\{A,I,K,R\})$	F	
52	$(D_m,\{I,R\})$			130	$(\mathrm{DC},\{A,I,K,R\})$	F	S
53	$(D_e,\{I,R\})$			131	$(C,\{A,I,K,T\})$		
54	$(D_s,\{I,R\})$			132	$(D_m,\{A,I,K,T\})$		
55	$(\mathrm{DC},\{I,R\})$			133	$(D_e,\{A,I,K,T\})$		
56	$(C,\{I,T\})$			134	$(D_s,\{A,I,K,T\})$		S
57	$(D_m,\{I,T\})$			135	$(\mathrm{DC},\{A,I,K,T\})$		
58	$(D_e,\{I,T\})$			136	$(C,\{A,I,R,T\})$	F	S
59	$(D_s,\{I,T\})$			137	$(D_m,\{A,I,R,T\})$	F	
60	$(\mathrm{DC},\{I,T\})$			138	$(D_e,\{A,I,R,T\})$	F	
61	$(C,\{K,R\})$			139	$(D_s,\{A,I,R,T\})$	F	
62	$(D_m,\{K,R\})$			140	$(\mathrm{DC},\{A,I,R,T\})$	F	S
63	$(D_e,\{K,R\})$			141	$(C,\{A,K,R,T\})$	F	

64	$(D_s,\{K,R\})$			142	$(D_m,\{A,K,R,T\})$	F	
65	$(\mathrm{DC},\{K,R\})$			143	$(D_e,\{A,K,R,T\})$	F	
66	$(C,\{K,T\})$			144	$(D_s,\{A,K,R,T\})$	F	S
67	$(D_m,\{K,T\})$			145	$(\mathrm{DC},\{A,K,R,T\})$	F	S
68	$(D_e,\{K,T\})$			146	$(C,\{I,K,R,T\})$	F	S
69	$(D_s,\{K,T\})$			147	$(D_m,\{I,K,R,T\})$	F	
70	$(\mathrm{DC},\{K,T\})$			148	$(D_e,\{I,K,R,T\})$	F	
71	$(C,\{R,T\})$			149	$(D_s,\{I,K,R,T\})$	F	
72	$(D_m,\{R,T\})$			150	$(\mathrm{DC},\{I,K,R,T\})$	F	S
73	$(D_e,\{R,T\})$			151	$(C,\{A,I,K,R,T\})$	F	S
74	$(D_s,\{R,T\})$			152	$(D_m,\{A,I,K,R,T\})$	F	
75	$(\mathrm{DC},\{R,T\})$			153	$(D_e,\{A,I,K,R,T\})$	F	
76	$(C,\{A,I,K\})$			154	$(D_s,\{A,I,K,R,T\})$	F	S
77	$(D_m,\{A,I,K\})$			155	$(\mathrm{DC},\{A,I,K,R,T\})$	F	S
78	$(D_e,\{A,I,K\})$						

As discussed in the background of the conflict, the main point of disagreement among the five littoral states after the collapse of the USSR in 1991 was that the newly independent states, Azerbaijan, Kazakhstan and Turkmenistan, preferred exclusive economic zones by division of the Caspian Sea, while Iran and Russia, which possess other economic resources, favoured the "condominium regime". As shown in Table 5.18, both of the states $(C,\{I,R\})$ and $(D_s,\{A,K,T\})$ are stable but infeasible under the T = 19 assumption. In negotiations between 1991 and 1997, stability with infeasibility can be interpreted as a case of deadlock. Generally, stable but infeasible states cause impasse in the negotiation process because infeasibility implies that the coalition associated with the state is not strong enough to enforce an agreement, while stability indicates that there is no movement from this state.

Table 5.18: Caspian Sea Model verification

Time	Initial State	Feasibility	Stability	Result
After the collapse of USSR in 1991	$(C,\{I,R\})$	Infeasible	Stable	Deadlock
	$(D_s,\{A,K,T\})$	Infeasible	Stable	Deadlock
1997	$(\mathrm{DC},\{R\})$	Infeasible	Unstable	Movement

The deadlock was relaxed in 1997 when Russia changed its priorities, in an apparent effort to become more pragmatic and constructive. It suggested that the two historical treaties with Iran (dating from 1921 and 1941) were still valid, implying that the surface of the Caspian Sea should be administered as a condominium. At the same time, it argued that the seabed should be divided among the five littoral states according to the modified median line method. As Table 5-18 indicates, the state $(\mathrm{DC},\{R\})$ is not stable; there are some movements away from it. Using the Negotiation Support System explained in Chapter 4, we trace all movements from the initial state $(\mathrm{DC},\{R\})$, in Figure 5.1.

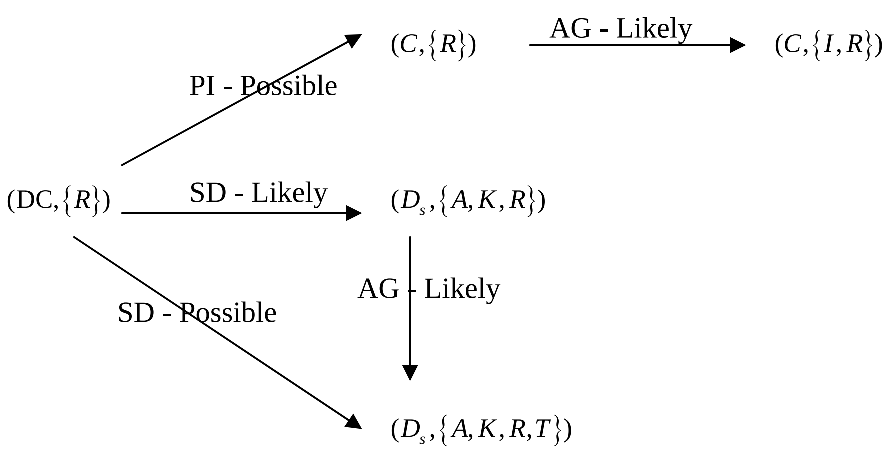

Figure 5.1: The tree of possible outcomes from $(\mathrm{DC},\{R\})$

As illustrated by Figure 5-1, which continues to assume T = 19, it is likely that Russia will support the ultimate division of the Caspian Sea. The reality matches this prediction. On May 14, 2003, a multilateral agreement on the dividing lines of the Caspian seabed was signed by the Republic of Azerbaijan, the Republic of Kazakhstan and the Russian Federation. Iran is very concerned that Turkmenistan may join this agreement, which would weaken Iran's position very much. Iran demanded that the Sea be divided equally, motivating Turkmenistan not to accept DC or D_S , since equal division of the Caspian Sea is the best alternative for Turkmenistan. Since there is no significant contrast between what the model describes as the most likely outcomes of the previous negotiations and what happened in reality, we interpret the negotiation model as verified.

5.3.2 Prediction of the outcomes of the Caspian Sea negotiations

We now apply the proposed methodology to predict the most likely outcomes of the continuing Caspian Sea negotiations. We mentioned that the five Caspian Sea states have agreed that the legal regime of the Caspian Sea should be determined unanimously. Therefore, it is reasonable that the threshold of all alternatives be set at T= 27 instead of T= 19 in the negotiation support system described in Chapter 4. In this case, only unanimous agreements over the five alternatives are feasible. Taking other parameters of the negotiation as identical to those referred in Table 5.16, the stable states of this negotiation are as shown in Table 5.19. There are 38 stable states, although only the five unanimous agreements are feasible.

Table 5.19: Stable states of the Caspian Sea negotiations

State ID	State	Feasibility	State ID	State	Feasibility
23	$(D_e,\{T\})$		118	$(D_e,\{I,R,T\})$	
40	(DC, $\{A,R\}$)		123	$(D_e,\{K,R,T\})$	
43	$(D_e,\{A,T\})$		125	(DC, $\{K,R,T\}$)	
51	$(C,\{I,R\})$		126	$(C,\{A,I,K,R\})$	
58	$(D_e,\{I,T\})$		132	$(D_m,\{A,I,K,T\})$	
65	(DC, $\{K,R\}$)		133	$(D_e,\{A,I,K,T\})$	
68	$(D_e,\{K,T\})$		134	$(D_s,\{A,I,K,T\})$	
73	$(D_e,\{R,T\})$		136	$(C,\{A,I,R,T\})$	
75	(DC, $\{R,T\}$)		138	$(D_e,\{A,I,R,T\})$	
81	$(C,\{A,I,R\})$		143	$(D_e,\{A,K,R,T\})$	
88	$(D_e,\{A,I,T\})$		144	$(D_s,\{A,K,R,T\})$	
95	(DC, $\{A,K,R\}$)		145	(DC, $\{A,K,R,T\}$)	
98	$(D_e,\{A,K,T\})$		146	$(C,\{I,K,R,T\})$	
99	$(D_s,\{A,K,T\})$		148	$(D_e,\{I,K,R,T\})$	
103	$(D_e,\{A,R,T\})$		151	$(C,\{A,I,K,R,T\})$	F
105	(DC, $\{A,R,T\}$)		152	$(D_m,\{A,I,K,R,T\})$	F
106	$(C,\{I,K,R\})$		153	$(D_e,\{A,I,K,R,T\})$	F
113	$(D_e,\{I,K,T\})$		154	$(D_s,\{A,I,K,R,T\})$	F
116	$(C,\{I,R,T\})$		155	(DC, $\{A,I,K,R,T\}$)	F

The final conclusions indicate that among the five unanimous agreements, state $(D_m,\{A,I,K,R,T\})$ is the most likely enduring legal status of the Caspian Sea, and $(D_s,\{A,I,K,R,T\})$ is second most likely. Figure 5.2 shows different ways that the first outcome, $(D_m,\{A,I,K,R,T\})$, unanimous agreement over the division of the Caspian Sea based on International Law applying to Seas, might evolve.

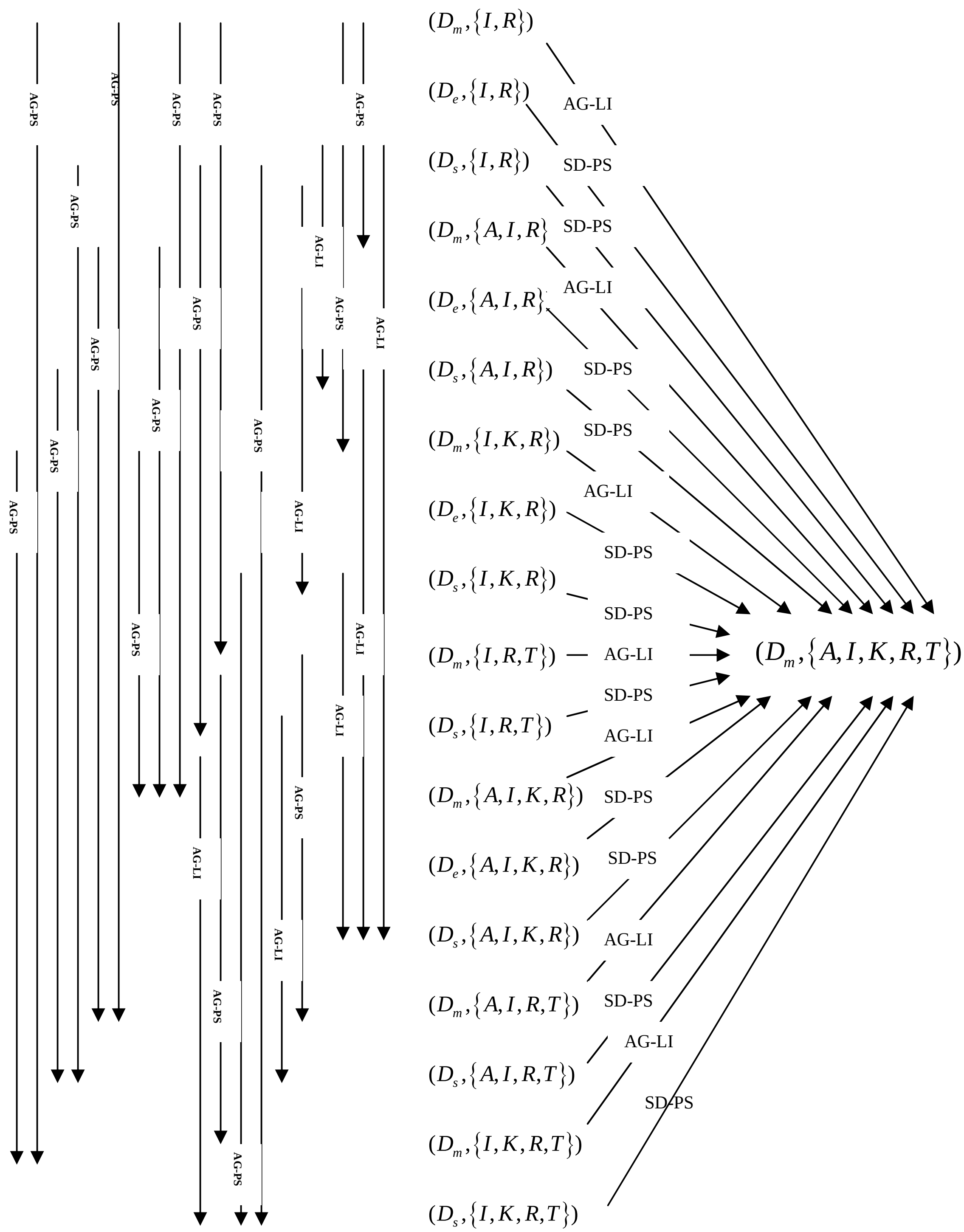

Figure 5.2: Different paths to unanimous agreement on division of the Caspian Sea based on the International Law applying to Seas

5.3.3 Sensitivity Analysis of the Caspian Sea negotiation model

At the beginning of Section 5.3, we referred to the states' preferences. Those strict preferences over the five alternatives were estimated based on assessments of the states' national economic, political and military interests. If we suppose that the states are much more concerned about economic rather than political or military issues, then their preferences are slightly changed, as follows:

Azerbaijan **:** $D_s > D_m > DC > D_e > C$

Iran **:** $C > D_e > D_m > DC > D_s$

Kazakhstan **:** $D_s = D_m > DC > C > D_e$

Russia **:** $C > DC > D_s = D_m > D_e$

Turkmenistan: $D_e > D_s > D_m > DC > C$

Under the new circumstances, Azerbaijan and Turkmenistan no longer consider D_m to be an acceptable alternative because, unlike Kazakhstan and Russia, these two states own a greater share of the Caspian Sea under D_s compared with D_m. In other words, the only acceptable alternative for Azerbaijan is D_s, and for Turkmenistan D_s or D_e. Other parameters of the negotiation in this sensitivity analysis are exactly identical to those in Section 5.3.2. Applying the proposed negotiation support system produces more stable states. Table 5-20 shows the new stable states in this sensitivity analysis. Note that all stable states shown in Table 5-19 remain stable. Also, all new stable states shown in Table 5-20 are infeasible.

Table 5.20: New stable states in the sensitivity analysis of the Caspian Sea negotiation model

State ID	State	State ID	State
12	$(D_m, \{K\})$	107	$(D_m, \{I, K, R\})$
47	$(D_m, \{I, K\})$	112	$(D_m, \{I, K, T\})$
62	$(D_m, \{K, R\})$	127	$(D_m, \{A, I, K, R\})$
77	$(D_m, \{A, I, K\})$	147	$(D_m, \{I, K, R, T\})$

As the results show, the change in priorities for the countries from political issues to economic issues increases the number of stable states. More specifically, the number of agglomeration movements and strategic disimprovements decreases due to the reduction in acceptable alternatives for Azerbaijan and Turkmenistan. In particular, state $(D_m, \{A, I, K, R, T\})$ is less likely to appear as the outcome, compared with the previous analysis in Section 5.3.2. Among the five unanimous agreements, state $(D_s, \{A, I, K, R, T\})$ is most likely as the enduring legal status of the Caspian Sea. However, D_s and D_m are not too far from each other (see Table 2.7) as both indicate similar divisions of the Caspian Sea. Figure 5-3 shows different ways that this state, unanimous agreement on the division of the Caspian Sea based on Soviet maps, might evolve.

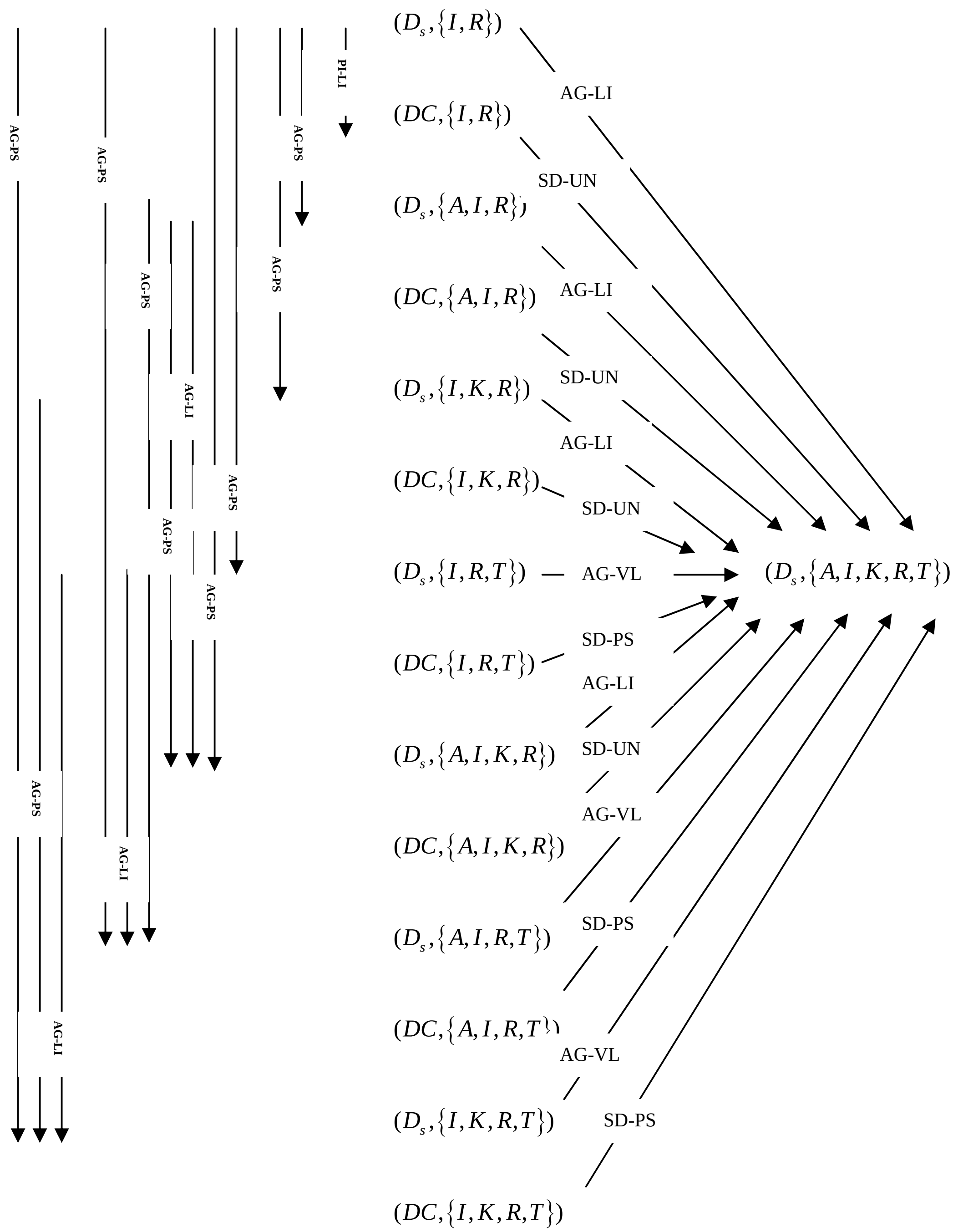

Figure 5.3: Sensitivity analysis for Caspian Sea negotiations -

Different paths leading to the unanimous agreement on $(D_s,\{A,I,K,R,T\})$

5.4 Conclusions and Summary

The methodology proposed in chapter 4 is applied in this chapter to model and analyse multilateral negotiations over the legal status of the Caspian Sea. The notion of power is discussed at the beginning of this chapter. Since the weights of the DMs are not clearly stipulated in the Caspian Sea negotiations, they are estimated based on the capability of the DMs in the negotiation process. To measure DMs' weights quantitatively, 11 criteria that can be considered to be important determinants of countries' capabilities in Caspian Sea negotiations are discussed, evaluated, and integrated using a Multi Criteria Decision Analysis model, and the Data Envelopment Analysis (DEA) method that finds the most favourable set of relative importance of different criteria for each country is applied.

A model of Caspian Sea negotiations is applied to verify to what extent the proposed methodology can predict the observed outcomes of the negotiations over the legal status of the Caspian Sea. Since there is no significant contrast between what the model describes as the most likely outcomes of the previous negotiations and what happened in reality, the negotiation model can be interpreted as verified.

The proposed methodology is applied in Chapter 5 to predict the most likely outcomes of the continuing Caspian Sea negotiations. The final conclusions indicate that unanimous agreements over the division of the Caspian Sea are the most likely outcomes that can be predicted as the enduring legal status of the Caspian Sea. The results of sensitivity analysis show that minor changes in input data of the model do lead to slightly different outcomes.

Chapter 6

Case Study 2 – Epton Site Redevelopment Negotiations

6.1 Introduction

In this Chapter, the methodology proposed in Chapter 3 is applied to actual negotiations over the redevelopment of a brownfield project at the Epton site located in Kitchener, Ontario, Canada. The objective is to ensure that the new methodology is flexible enough to model more real-world cases. Moreover, we want to test how well the actual outcomes of the real world negotiations match the most likely outcomes identified by the methodology. We start with a general introduction to brownfield redevelopment projects, then we chronicle the history of the Epton site, and finally we model and analyze the negotiations over the redevelopment of this site.

Brownfields are defined by the United States Environmental Protection Agency (USEPA) as abandoned or idled properties that are contaminated or potentially contaminated as a consequence of previous usage. They are both a problem and a point of interest for urban centers around the world (USEPA, 1997). Brownfields vary in size, location, age and past use, and can range from abandoned corner gas stations to large, multi-acre former manufacturing plants that have been closed for years. (The Community Environmental Resource Program, 2008)

Although brownfields are sometimes associated with reduced human health and environmental quality and with increased crime rates, and may be seen by developers, citizens and local governments as carrying a stigma, their redevelopment provides opportunities to reduce urban sprawl, improve human health and environmental conditions, and increase tax revenue for the local government (Greenberg, et al., 1998; DeSousa, 2003). Many parties have interests in the environmental, social and economic impacts of brownfield redevelopment projects. Dair and Williams (2006), De Sousa (2003; 2000) and Greenberg et al (1998; 2000) all conclude that the key decision makers are private and public developers; federal, regional and local government agencies; and community groups.

We now focus on a specific brownfield redevelopment project, the Epton site. After recounting the history of this property, we model and analyze multilateral negotiations over its redevelopment.

6.2 History of the Epton Site

The property known as the 'Epton site' is located on approximately three hectares at the edge of the business district in Kitchener, Ontario, Canada. At the time it was closed, in 1996, it included five buildings with a total floor area of nearly 46,000 square meters. The oldest buildings dated from 1919, with additions through 1957. The site was used for the manufacturing of plastic and rubber products (Larson, 2008).

The plant was owned and operated by B.F. Goodrich Canada Inc. (a subsidiary of The B.F Goodrich Company, a US corporation) until 1983, at which time the property was sold to Epton Industries Limited. As a part of the transaction, Goodrich Canada indemnified Epton for certain claims that could arise out of environmental contamination that may have occurred prior to 1983. In 1993, Goodrich (USA) spun off its Geon Vinyl Division as an independent publicly-traded Corporation, The Geon Company. Geon Canada Inc., a wholly owned subsidiary of The Geon Company, the successor of Goodrich Canada, including the Epton property. In 2000, The Geon Company became the PolyOne Corporation and Geon Canada was renamed PolyOne Canada. The following is a timeline representing the history of Epton site from 1994 until the present.

April 1994

Bill Thomson, President of Epton, demanded that Geon accept responsibility for environmental contamination at the Epton site, based upon the indemnifications given to Epton by Goodrich in the 1983 sale. Geon had no obligation to agree to Epton's demand, inasmuch as the indemnification (as acknowledged by Epton), would apply only if there were a government order, for example from the Ontario Ministry of the Environment (MOE), to remediate or compensate for environmental damage. At the time, no such action had been taken, or even threatened. Other reasons why Geon could have resisted Epton's demand included the less-than-definitive wording and the fact that "after the sale" Epton had probably contributed substantially to the contamination, thus voiding the indemnification. Nevertheless, in light of Epton's precarious financial situation, Geon believed that, there was a strong possibility that the MOE would step in and order remedial action, as might be inevitable in the event of bankruptcy, and therefore denied not to force the issue. Usually, remediation is less costly and less complicated if it is undertaken voluntarily.

Geon sent Bill Thompson a letter containing a proposed 'standstill' agreement. Under the terms of the agreement, the two parties would hire a consultant to conduct a remedial investigation at the site and even begin actual remediation, if indicated. The parties would direct the consultant by consensus, with no formal direction or work plan, and would split the costs 50-50, with the understanding that the costs could (retroactively) be reallocated sometime in the future, by agreement, litigation, or otherwise. The agreement could be revoked by either party at any time, and each party reserved any claims or defenses. The agreement was simple and notably lacking in legalese, relying instead upon the common interest of both parties to address the environmental issues without acknowledging or commiting to any specific responsibility or outcome. Thomson signed a copy of the letter and sent it back without any changes. Shortly thereafter, Epton and Geon retained CH2M Gore & Storrie ('CG&S', an environmental consultant now named CH2M Hill) to perform the remedial investigation. "Geon and Epton advised officials of the MOE that an environmental investigation was taking place and kept the agency apprised of those activities. Significant soil and groundwater contamination was found. After notifying Epton, Geon asked CG&S to start pumping the contaminant out through the monitoring well" (Larson, 2008).

August 1995

Epton was deemed to be bankrupt, and ceased manufacturing operations (except for limited production undertaken by the Trustee in Bankruptcy on behalf of General Motors). This presented several problems for Geon and the Epton site remediation plan.

First, the joint support for the remediation program came to an end. In order to continue the work, Geon agreed to continue the investigation and preliminary remediation activities on a voluntary basis and to pay 100 percent of the consultant's fees, pending further resolution of issues in bankruptcy proceedings. Geon also agreed to reimburse CG&S for Epton's unpaid invoices.

Second, when Epton went into receivership, potential liability for the environmental conditions at the site fell upon numerous other parties, including prior property owners (including Goodrich/Geon), the Trustee itself, secured creditors, certain interim operators, and others associated with plant operations over the years. Bill Thomson (Epton), Ted Pollock (CG&S), and Lee Larson (Geon) met regarding the bankruptcy filing. All agreed that Geon was responsible for about 80 percent of the contamination at the site, and Epton about 20 percent. An important aspect of their agreement is that it not only postponed negotiations over allocation of responsibility, but also provided a mechanism to assist the parties to reach eventual agreement on financial responsibility.

Geon wanted to avoid litigation for at least three reasons. First, the transactional (litigation) costs would likely be enormous, considering the complexity of the issues and the number of parties to the litigation and their disparity. Second, as is customary in environmental liability cases, the remediation would probably be carried out (after an apportionment of liability) by a committee or organization composed of all the potentially liable parties, a notoriously wasteful, cumbersome, and ineffective process. And, third, any remediation program would be overseen by the MOE, which could increase costs exponentially and delay completion by years.

Accordingly, Geon proposed an agreement among it, the Trustee, and the creditors that would (1) allow Geon access to the property to continue its remediation program (on a voluntary basis), (2) grant Geon a lien on the property for its remediation costs, (3) grant to Geon an option to purchase the property (for one dollar), (4) insulate Geon from some possible claims, and (5) vacate all liens and mortgages on the property. In return, Geon would forego all claims against the other parties, including the Trustee, for past and future cleanup costs and indemnify them against any environmental claims.

A month after the bankruptcy filing, the Trustee and all creditors but one formally accepted Geon's proposal, without significant changes, and executed an agreement, the Geon Canada

Remediation Access Agreement. Geon Canada's environmental investigation and remediation efforts were not delayed by the Epton bankruptcy. Geon had submitted the results of its preliminary (Phase I) studies to the MOE in July, 1995 and met with the Ministry in August to discuss the status of the investigation and remediation project. Later in the month, the Ontario Court of Justice agreed that the property had no value and authorized the Trustee to abandon it, subject to completion of its duties it had agreed to, including these given in the Remediation Access Agreement.

November 1995

In November, the bankruptcy Trustee wrote to the City of Kitchener and Regional Municipality of Waterloo, informing them that the buildings would be stripped, the utilities and fire protection would be terminated, and the site would be abandoned. The Trustee offered custody (and, presumably, ownership) of the site to the City or Region, but both declined. As Geon continued its environmental investigation and remediation program, the Trustee proceeded to cannibalize the 500,000 square feet of buildings on the property, removing the fixtures, plumbing, wiring, machinery, HVAC systems, scrap metal, etc. By early 1996 the buildings were gutted, windowless eyesores.

January 1996

On January 30, 1996, the Court granted Geon access to the property for the purpose of remediation, superseding the Trustee’s abandonment of the property and ultimate discharge. The Court also granted a lien against the property in favor of Geon for past and future remediation costs.

The City of Kitchener became increasingly concerned about the extreme fire and safety hazard presented by the gutted and abandoned buildings. Because of the Trustee’s abandonment of the property, the City could not acquire title, and abate the hazards, quickly. Moreover, acquisition of title would expose the City to substantial environmental liability, and the estimated cost to the City to demolish and remove the buildings would exceed $1.5 million. The City urged Geon to exercise its option, purchase the property, and abate the hazards.

During 1995 and 1996, representatives of Geon met with the City to discuss the status of the property. The City had liens of over $1 million on the property, including arrears of realty taxes (which were continuing to accrue) and unpaid electricity charges. The City was extremely concerned because it believed that, if the site were abandoned, it would be left to deal with the practical problems that would inevitably arise. The City also feared that it would not be able to recover back taxes, and advanced proposals involving a tax write-off to encourage a private party to demolish the building and develop the property.

The City's long-term objective was to make the property available for future use so that it would contribute positively to the community and generate tax revenue. The reaction of Geon to the idea of taking title to a contaminated factory was understandably cool, but it eventually agreed. Geon made a simple proposal: Geon would exercise its option to purchase the property and demolish the buildings by October 31, 1997, if the City would forgive past and ongoing real estate taxes (and other charges) up to that date.

September 1996

On September 16, 1996 the Kitchener City Council passed a resolution authorizing the write-off of past and future realty taxes if Geon Canada (or a subsidiary) spent the equivalent amount, or less to demolish the buildings and clear the property. Shortly thereafter, the Kitchener-Wilmot Hydro Commission wrote off the electricity charges relating to the property. The total of the write-off, was approximately $1.2 million.

On September 26, 1996 a new Canadian corporation, LP Holdings Inc. ("LPH"), was incorporated as a wholly-owned subsidiary of Geon Canada. The articles of incorporation of LPH limit its objects to acquiring the Epton property, securing and demolishing the buildings, preparing the property for lease or sale, leasing and selling the property, and anything reasonably incidental to the foregoing. The articles also provide that, in all matters, due regard must be paid to the interests and input of the Kitchener-Waterloo community.

LPH has two directors, one a PolyOne Canada (at that time, Geon Canada) employee and the other an independent resident of Waterloo, Ontario. LPH is committed to dispose of the property (by donation or sale) for public use or for other purposes serving the community’s interest. To guarantee this commitment, LPH’s charter grants to the City of Kitchener the power to appoint a third (and controlling) director to the LPH Board. Thus, Geon cannot control LPH or its activities, and, if necessary to protect the public interest, the City and the independent director can together take control of LPH.

On September 27, Geon (Canada) and LPH agreed that Geon would assign to LPH its option to purchase the property. Under the terms of the LPH/Geon agreement, Geon agreed to indemnify LPH for historic remediation costs. On its part, LPH agreed that Geon would have access to the Epton site for environmental investigation and remediation, that Geon's cleanup need only to satisfy industrial standards (as determined by Geon), that Geon would be indemnified against future contamination charges, that the property would not be used, leased or sold for a purpose inconsistent with Geon's remediation program, and that Geon would be reimbursed for cleanup costs if the proceeds of any future sale exceed LPH's costs of operation and building demolition.

October 1996

LPH obtained the necessary court order on October 16th, and began the demolition process the next morning. In October, LPH arranged for the cleanup of trash and debris and solicited bids for Phase 1 of the rehabilitation (plant demolition) project. Phase 1 included demolition of the water tower and three smaller buildings, which presented the greatest safety hazards.

Thereafter, Phase 2 would include the demolition of the main building and the grading, seeding, and preparation of the vacant land for commercial disposition. LPH submitted an Extended Phase II (environmental remediation) report to MOE and requested a meeting in December. It also met with leaders to discuss the status and future uses of the property.

December 1996

On December 3, 1996, city officials, the MOE, and the general public attended an informational meeting held in Kitchener, at which representatives from LPH, Geon Canada, and CG&S, described in detail the environmental problems at the site, outlined remediation and rehabilitation plans, and answered questions. Geon disclosed that investigations to date had discovered soil and groundwater contamination, including naphtha and TCE, but confirmed that this contamination posed no danger to public health or safety. "Since December, 1994 onsite groundwater remediation had already resulted in substantial contaminant plume containment and significant improvement of the groundwater quality, but much remained to be done. Both LPH and Geon committed to make all environmental information available to the general public" (Larson, 2008).

The Phase 1 rehabilitation project was completed and draft bid specifications for the Phase 2 rehabilitation were released. Geon met with the MOE to review the Extended Phase II environmental report and discuss alternatives.

October 1997

Phase 2 was completed in October, 1997. The adverse public reaction normally associated with such a project was avoided by the inclusion of community input. LPH explored alternatives for the ultimate use of the property with community organizations. A group of citizens responded with a proposal to use the property as a site for an Olympic class aquatic sports center, which would benefit Kitchener-Waterloo, Ontario, and Canada. An *ad hoc* committee was formed to develop the concept, the Poseidon Project. The committee proposed to build a pool complex for four major aquatic sports, a wellness center, and athletic housing. LPH offered to donate the Epton property for that purpose, and worked with the Poseidon Committee to bring the concept to fruition. Neither LPH nor Geon would have received any economic benefit from the project.

While the Poseidon Project was being developed, LPH offered temporary use of the property to the City for purposes commensurate with the remediation activities at the site. The City used part of the property for public parking and undertook a beautification project along the King Street border. In April, 1999, the Poseidon Project received a boost when the City of Kitchener appropriated $130,000 to retain professional assistance for development of the project, the total cost of which was estimated at $60 to $80 million.

January 2001

In January, 2001, the completed architectural, financing, and business plans were presented to the City of Kitchener for approval. However, City Council declined to approve a $15 million capital contribution necessary to fund the project, primarily for political reasons, and the Poseidon Project had to be abandoned. LPH invited the City to identify other public or publicly beneficial uses for which the property might be sold or donated.

March 2001

The City was experiencing a severe shortage of parking in the area, and inquired about using the Epton site property for that purpose. To develop a parking lot, LPH and the City executed a three-year lease for the City on most of the property. LPH charged no rent and, the City agreed to maintain the property, and cover property taxes, and other expenses. The lease is still in effect, although the parking lot structures have since been removed.

March 2006

The City and the University of Waterloo identified the property as a potential site for a new Health Science Campus for the University, comprised of a pharmacy, satellite, medical school and clinics. A formal agreement was reached by the City of Kitchener and LPH for LPH to transfer title of the property to the City. The transfer was in stages, with the timing determined by minor remediation activities and Ministry approval.

October 2008 (the present time)

The parties (LPH, the City of Kitchener, and the University of Waterloo) are cooperating to obtain the environmental approvals necessary to effect the final transfer of the property to the City and, ultimately, the University. The pharmacy building is almost completed.

The history of Epton site is summarized in the Timeline diagram shown in Figure 6.1.

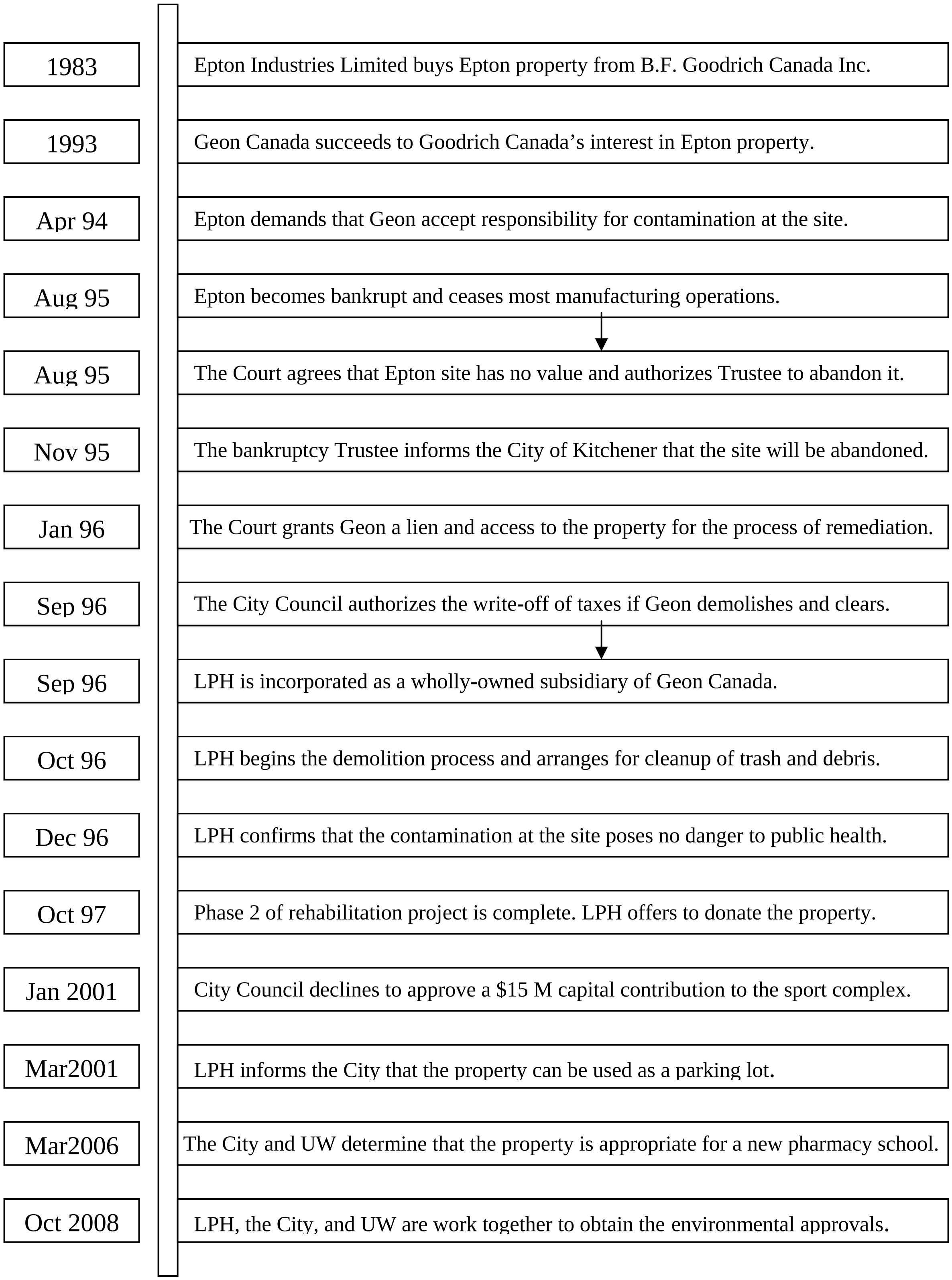

Figure 6.1 – Timetable diagram for the history of Epton site

6.3 Modeling Negotiations over the Redevelopment of the Epton Site

Now we identify the most likely outcome of negotiations over the ultimate use of the property using the proposed methodology. The model covers mainly the redevelopment of the Epton site.

6.3.1 Decision makers and alternatives

Based on the timeline presented above, the following DMs are included in the model of negotiations over the Epton site.

1) LPH
2) City of Kitchener
3) University of Waterloo

It may be argued by some that the citizens of Kitchener should be considered as the fourth DM because they may have independent interests and preferences. We do not consider the public to be an independent DM for the following reasons:

- The Public is not directly involved in negotiations among LPH, City of Kitchener and the University of Waterloo. Moreover, its interests are indirectly reflected in the decisions of the City of Kitchener, which is influenced by City Council whose members are elected. In other words, we assume that the possibility of improved service to citizens is a criterion in the City's decision making.
- Different citizens may have different preferences over the alternatives. For example, citizens may not agree as to whether or not parking is preferable to building a Sports Complex. It is the responsibility of the City Council to integrate the interests of the citizens.

It may also be suggested that the MOE should be considered as another DM. However, MOE is not directly involved in negotiations among LPH, City of Kitchener and the University of Waterloo. As long as the remediation meets its standards, MOE's role is not to prescribe any specific ultimate use for the site. Of course, different applications may need different levels of remediation, as determined by MOE (Gray, 2008). We now list all possible alternatives as the use of the site.

A: Do nothing

This alternative means leaving a vacant building with outstanding taxes and utility bills which would continue to accumulate from the previous owner, Epton. LPH would be responsible for remediation. According to the Adverse Affect rule, if there is a possibility of contaminating adjacent property, then the owner can be held accountable to remedy any environmental impacts.

B: Make the site safe

This alternative means that the city would undertake the removal of hazards, and LPH would demolish the building and level the site. But there would be no underground remediation, though the site would be safe for the public in accordance with health and safety standard, potentially permitting redevelopment.

C: Parking Lot

According to this alternative, the city forgives outstanding utility bills and taxes, while LPH pays for demolition and makes the site safe. The city then would develop a parking lot.

D: Sport Complex

In this alternative, the city forgives utility bills and outstanding taxes, while LPH pays for demolition and makes the site safe. Then, the city develops a sports complex on the site.

E: School of Pharmacy

According to this alternative, the city forgives utility bills and outstanding taxes, while LPH pays for demolition and makes the site safe. Then, the University of Waterloo builds a School of Pharmacy on the site with a substantial financial contribution from the city.

6.3.2 Ordinal preferences of decision makers over the alternatives

In this stage, we model the ordinal preferences of DMs over the specified alternatives. Table 6.1 lists the criteria Cost, Public Image, and Revenue that determine LHP's preferences over the five alternatives. For this DM, the weights of the criteria are assumed to be equal 3, 2, and 1, respectively. Cost includes taxes, utilities, site remediation, demolition, redevelopment, and ongoing expenses of property ownership. Public Image reflects environmental stewardship and public benefit increasing reputation and possibly leading to future contracts. Revenue means value added to the redeveloped site, including income, for LHP. The performance of each alternative for each criterion is quantified by a utility value between 0 and 10.

Table 6.1: The importance and performance of each criterion for LPH

LPH	Cost	Public Image	Revenue	Overall Evaluation	Ordinal Preference
	3	2	1		
A: Do nothing	10	0	0	**30**	2
B: Make the site safe	8	2	0	28	4
C: Parking lot	7	4	3	**32**	1
D: Sport Complex	4	6	0	24	5
E: School of Pharmacy	4	9	0	**30**	2
Ideal Overall Evaluation				60	

The utility values in Table 6.1 can be justified as follows:

- Under alternative B, LPH spends money just for demolition.
- Under alternative C, LPH spends money for both demolition and remediation. On the other hand, with a parking lot, there will be revenue for LPH. LPH and the City signed a three-year lease, under which the City could use the majority of the property to build a parking lot. LPH charged no rent and, in return, the City agreed to maintain the property, pay the real estate taxes, and establish a fund to pay certain other expenses related to property ownership. The City benefited from the use of the property and LPH was relieved of much of the ongoing expense of property ownership.
- Alternatives D and E may have a greater remediation cost.

Table 6.2 shows Cost, Public Benefit, and Revenue as the three criteria that determine the preferences of the City of Kitchener over the five alternatives. For this DM, the weights of the criteria are 2, 3, and 1, respectively. Cost includes initial capital investment and annual operating cost. Public Benefit indicates community benefits and respect for environmental liabilities. Revenue consists of potential taxes generated, and other possible income, for the City of Kitchener.

Table 6.2: The importance and performance of each criterion for City of Kitchener

City of Kitchener	Cost	Public Benefit	Revenue	Overall Evaluation	Ordinal Preference
	2	3	1		
A: Do nothing	8	0	0	16	5
B: Make the site safe	6	3	2	23	4
C: Parking lot	5	6	4	**32**	2
D: Sport Complex	3	7	2	29	3
E: School of Pharmacy	3	9	2	**35**	1
Ideal Overall Evaluation				60	

The utility values in Table 6.2 can be justified as follows:

- Under alternative A, the City of Kitchener has no significant cost. However, it receives no compensation for unpaid tax or utility bills on the property.
- Under alternative B, the City of Kitchener would undertake the removal of hazards. If the site is redeveloped, the City would receive tax revenue in the future.
- Under alternative C, the City of Kitchener pays for the development of a parking lot, maintains the property, and pays the real estate taxes. On the other hand, the parking lot generates income for the City.
- Under alternative E, the City of Kitchener transferred $30 million to the University of Waterloo for development of the School of Pharmacy through, the economic development investment fund. This alternative generates substantial revenue for the City as it receives a flat rate in liew of taxes.

Table 6.3 shows Cost, Public Service, and Revenue as the three criteria that determine the preferences of the University of Waterloo over the five alternatives. For this DM, the weights of the mentioned criteria are 1, 3, and 1, respectively. Cost includes initial development cost and annual operating cost. The utility value of cost for alternative E is considered 7, reflecting the $30 million received by the University of Waterloo from the City (Witmer, 2008).

Table 6.3: The importance and performance of each criterion for University of Waterloo

University of Waterloo	Cost	Public Service	Revenue	Overall Evaluation	Ordinal Preference
	1	3	1		
A: Do nothing	10	0	0	10	5
B: Make the site safe	10	1	0	13	2
C: Parking	10	1	0	13	2
D: Sport Complex	10	1	0	13	2
E: School of Pharmacy	7	10	4	**41**	1
Ideal Overall Evaluation				50	

Based on the results shown in the last columns of the Tables 6.1, 6.2 and 6.3, the ordinal preferences of DMs over the proposed alternatives are as follow:

- **LPH:** $C \succ E \sim A \succ B \succ D$
- **City of Kitchener:** $E \succ C \succ D \succ B \succ A$
- **University of Waterloo:** $E \succ B \sim C \sim D \succ A$

The acceptable alternatives according to each DM are specified in Table 6.4, assuming that each DM accepts those alternatives for which their overall evaluations meet at least half of the ideal overall evaluation.

Table 6.4: The acceptable alternatives for each DM

Decision Maker	The acceptable alternatives
LPH	C, E, and A
City of Kitchener	E and C
University of Waterloo	E

As an exercise, in Appendix A, we estimate each DM's weight in the decision making process which is important if the threshold of feasibility is something other than consensus.

6.4 Analysis

We start from the initial state, determine all possible movements and their associated likelihoods, and then trace the subsequent states to identify the most likely outcome according to the proposed methodology, explained in Chapter 3. The status quo considered in this analysis is state supporting B in which both LPH and the City of Kitchener agree to make the site safe. This was the actual situation in September 1996. Figure 6.2 shows all possible movements from the initial state to the subsequent states. On each arrow, the type of the movement and its associated likelihood are indicated. For example, the movement from the status quo to the unanimous agreement over parking lot is a disloyalty move and likely.

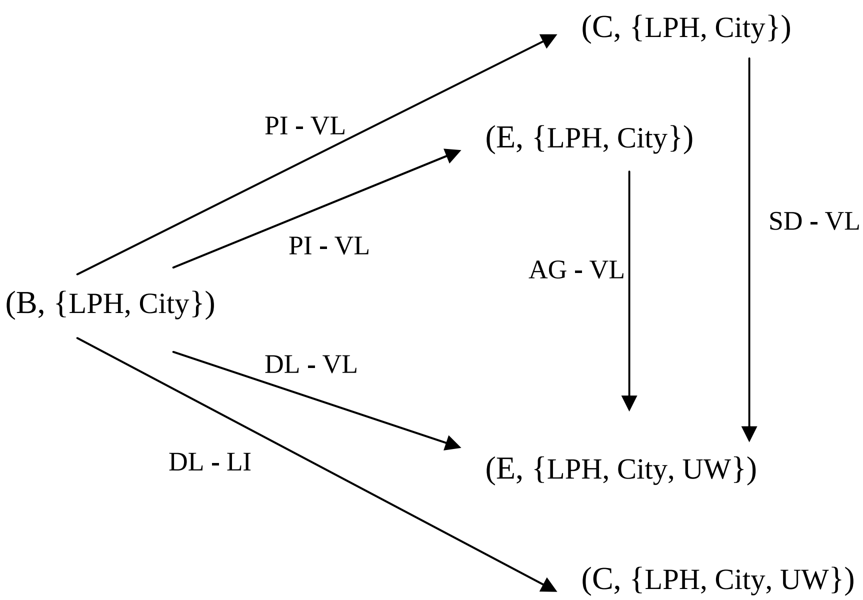

Figure 6.2 – Tree of movements from the initial state to the possible outcomes

In our analysis, we assume that a state is feasible if and only if it is a unanimous agreement over an alternative. In other words, only those alternatives can be established that are supported by all DMs. As illustrated in Figure 6.2, all four types of movements, Preferential Improvement, Agglomeration, Disloyalty, and Strategic Disimprovement, may occur in the process of negotiations over the redevelopment of Epton site. As depicted in the figure, all of these movements are very likely except movement from the status quo to the unanimous agreement over alternative C, which is only likely.

The results indicate that two states could occur as the potential outcome of negotiations: unanimous agreement over alternative C and unanimous agreement over alternative E. In Chapter 3, Section 3.3.1, the Likelihood Measure was defined as a number indicating, for each potential outcome of a negotiation, how likely it is to be the final outcome. To estimate the Likelihood Measure for two potential outcomes of this negotiation, we ascribe a subjective probability, like 60% and 80%, to each of Likely and Very Likely, respectively. Then

$$(E, \{LPH, City, UW\}) \longrightarrow (0.8)(0.8) + (0.8)(0.8) + (0.8) = 2.08$$
$$(C, \{LPH, City, UW\}) \longrightarrow 0.6$$

Since the sum of 2.08 and 0.6 is not 1, we normalize them. Table 6.5 shows the resulting Likelihood Measures. (Recall that the Likelihood Measure is not a probability.)

Table 6.5: Likelihood Measure for potential outcomes

potential outcome	Likelihood Measure
(E, {LPH, City, UW})	0.776
(C, {LPH, City, UW})	0.224

The analysis shows that we should expect that the unanimous agreement over alternative E is much more likely to occur as the ultimate outcome. This happened in reality, when all DMs agreed to redevelop the Epton site for having School of Pharmacy. Figure 6.3 shows the actual sequence of movements from the status quo.

(B,{LPH, City}) $\xrightarrow{\text{Preferential Improvement}}$ (C,{LPH,City}) $\xrightarrow{\text{Strategic Disimprovement}}$ (E, {LPH,City,UW})

Figure 6.3 – The actual sequence of movements from the status quo

This sequence of movements matches a path of the tree shown in Figure 6.2. Note from the tree that there are two other paths starting from the status quo and ending at the actual outcome of negotiations, but these two paths were not followed.

We now assume that LPH is not indifferent between alternatives A and E. Let us suppose that it prefers A to E, so that the revised preferences of this DM over the alternatives would be: $C \succ A \succ E \succ B \succ D$

Under the new preferences of LPH, the tree of movements shown in Figure 6.2 remains without change except for the likelihood of movement from the status quo to the state (E, {LPH, City}) which changes to Likely. Also, in the strategic disimprovement from state (C, {LPH, City}) to unanimous agreement over the School of Pharmacy, we assume that LPH is willing to accept alternative E rather than C. Therefore, the fallback distance of LPH is now considered to be at least 2, because LPH must retreat two levels from C to E in this disimprovement. The resulting Likelihood Measures would be slightly different due to this minor change. Table 6.6 shows the Likelihood Measure for potential outcomes under the new preferences of LPH. It indicates that the unanimous agreement over the School of Pharmacy is slightly less likely to occur as the ultimate outcome of negotiation if LPH prefers Do Nothing to School of Pharmacy.

Table 6.6: Likelihood Measure for potential outcomes under the new preferences of LPH

potential outcome	Likelihood Measure
(E, {LPH, City, UW})	0.762
(C, {LPH, City, UW})	0.238

It is also possible that the University of Waterloo is indifferent between alternatives A and D and does not prefer D to A. In other words, we assume new preferences for this DM as follows: $E \succ B \sim C \sim D \sim A$

Under the new preferences of the University of Waterloo, nothing changes. Possible moves, the likely outcomes of negotiation and the corresponding Likelihood Measures remain without change.

6.5 Summary

The remediation and redevelopment of the Epton site has been very challenging, costly and time consuming for the DMs. In the end, LP Holding, the City of Kitchener and the University of Waterloo unanimously agreed to build a School of Pharmacy after years of negotiations and discussions of several alternatives. The multilateral negotiations over the Epton site brownfield redevelopment project are modeled and analyzed in this chapter, using the methodology of Chapter 3. The results show that the decisions on the use of the property followed the most likely path described and predicted by the model. Additionally, some sensitivity analyses over the preferences of DMs indicate that possible alternative preference orders would have little or no effect on the conclusions from the model.

Chapter 7

Conclusions and Future Work

7.1 Summary of Contributions

In this thesis, new definitions and a novel methodology for modeling and analyzing of multilateral negotiations have been developed and applied to two real-world cases. The proposed methodology identifies the most likely outcomes of multilateral negotiations when reaching an agreement is the main objective of the DMs. This methodology is mostly descriptive. It is specifically designed for convenient application to asymmetric multilateral negotiations. Particular contributions of this thesis are as follows:

- Defining new concepts including *State, Acceptability*, *Feasibility*, *Stability*, and *Fallback Distance*.
- Formally defining different types of movements from one state to another, including *preferential improvement, agglomeration, disloyalty move*, and *strategic disimprovement*.
- Investigating the theoretical properties of the different types of movements and proving that all four movement types are mutually exclusive.
- Proposing necessary criteria and developing algorithms to measure the likelihood of different types of movements and calculating likelihood measures for predicted outcomes.

- Illustrating the evolution of negotiations from the status quo to the predicted outcomes using a tree structure.

Like other models, the methodology proposed in this thesis has some limitations. So far, the following limitations have been investigated:

- The alternatives discussed in the model are points in a discrete space. Because the set of possible agreements is pre-specified, learning is not possible and the outcome of negotiation cannot be a combination of the proposed alternatives, so the model is not integrative. However, one can combine alternatives in any sensible way and get a new model which in turn can be analyzed.
- The condition defined to determine feasibility of states can handle the situations in which veto power is possible, but the assumption that sums of weights measure effective power does not take into account possible synergies of players, positive or negative.

Like existing models discussed in Chapter 2, the proposed methodology is applied to predict the most likely outcomes of the continuing Caspian Sea negotiations. The most challenging step in modeling the Caspian Sea negotiations is to estimate the DMs' weights. To measure them quantitatively, eleven criteria considered to be important determinants of countries' capabilities in the Caspian Sea negotiations are discussed, evaluated, and integrated using a Multi Criteria Decision Analysis model. The Data Envelopment Analysis (DEA) method finds the most favourable relative importance scores for criteria and uses them to estimates the weights. The results of applying the existing models and the proposed methodology to the Caspian Sea negotiations include the following:

Social Choice Rules: We applied some common social choice rules including Condorcet winner, Borda Score, Plurality Rule, Median Voting Rule, Majoritarian Compromise, and Condorcet's Practical Method to find a "socially optimal" resolution. All of the applied rules recommend division of the Caspian Sea based on Soviet maps. Only the plurality rule recommends the condominium approach in addition to division based on Soviet maps.

Fallback Bargaining Procedures**:** Unanimity Fallback Bargaining recommends two compromise alternatives: division of the sea based on the International Law of the Seas, and division of the seabed based on the International Law of the Seas, with condominium status on the surface. These two alternatives maximize the minimum satisfaction of all of the DMs. The first compromise alternative has a higher mean rank than the second one. Hence, the division of the Caspian Sea based on the International Law of the Seas seems most appropriate, but this resolution would require some countries to be more flexible about their impasse (walk-away) levels. For the case of the Caspian Sea negotiations, the unanimity decision rule should be taken into account. In particular, the majority decision rule does not yield a sustainable resolution.

Bankruptcy Procedures: We represented the dispute in financial terms and applied three well-known bankruptcy procedures, which are fair division methods that apply to monetary claims. We recommended an allocation of the Caspian seabed resources across the five Caspian states. The *constrained equal award rule* is socially optimal according to all of the applied social choice rules. The Unanimity Fallback Bargaining procedure selects the *proportional rule*. Hence, resource allocation based on this rule maximizes the minimum satisfaction across all five states.

The proposed methodology: In Chapter 5, applying the proposed methodology indicates that unanimous agreements over the division of the Caspian Sea, either based on the International Law of the Seas or based on Soviet maps, is the most likely outcome that can be predicted as the enduring legal status of the Caspian Sea. The sensitivity analysis shows that minor changes in input data of the model do lead to slightly different outcomes.

Based on the conceptual model for multilateral negotiations proposed in Chapter 3, a practical Negotiation Support System is designed and implemented. This NSS increases the speed of calculations, as well as helps us to avoid mistakes in manual calculations. All movements from initial states to subsequent states, in addition to their associated likelihoods, are clearly illustrated. All stable states are distinguished by a check mark and feasible stable states are shown distinctively in red colour and bold. The Negotiation Support System explained in Chapter 4 has been implemented in Microsoft Access using Microsoft Visual Basic.

The multilateral negotiations over the Epton site redevelopment project are modeled and analyzed in Chapter 6, using the proposed methodology. The objective is to ensure that the new methodology is flexible enough to model real-world cases, such as negotiations over the redevelopment of a brownfield. Moreover, we wanted to test how well the actual outcomes of the real world negotiations match the most likely outcomes identified by the methodology. The results show that decisions on the use of the property followed the most likely path described and predicted by the model.

We call what is proposed in Chapter 3 a methodology as it is a family of methods, including identifying movements from one state to others, illustrating the evolution of negotiation from the initial state by a tree, and estimating the likelihood for the predicted outcomes of a negotiation. More specifically, the proposed methodology includes some algorithms which are formal techniques, like those for determining the likelihood of different types of movements. A model is a specific representation of a phenomenon. In this thesis, we have two models, a model for the Caspian Sea negotiations, and a model for the Epton site redevelopment negotiations.

This thesis constitutes multidisciplinary research, as it utilizes different branches of knowledge including applied mathematics (game theory), computer science and programming, international relations, and environmental management. However, negotiation modeling and analysis in this thesis has been developed from an overall systems engineering perspective.

7.2 Future Research Directions

Although substantial theoretical advances have been achieved within our new paradigm for modeling and analyzing of multilateral negotiations, some critical issues remain open. Some promising research opportunities are as follows:

- Investigating more theoretical properties among the defined movements, and their associated likelihoods. The new properties can be expressed by relevant theorems.

- Applying the proposed methodology to more real-world cases including some other brownfield redevelopment projects, such as negotiations over the redevelopment of the coal tar site located in downtown Kitchener, Ontario, Canada, to predict the ultimate use of this site.
- Applying existing models, such as social choice rules and fallback bargaining procedures, to the negotiations over the Epton site redevelopment project. The comparison between the outcomes predicted by the existing models and those forecasted by the proposed methodology and the actual outcome as the ultimate use of the Epton site, can determine the robustness of the proposed methodology compared with other existing models.
- Examining other related aspects of the Caspian Sea negotiations model by developing it further or revising it. For example, if we include pipeline development, in addition to the legal status of the Caspian Sea, then oil transit countries like Turkey and Georgia, and Caspian Sea oil consumers including Western European stakeholders would be relevant decision makers and should be taken into account in the investigation.
- Further applications may cause development of the theoretical framework and suggest other types of movements, other rules for deciding stability, and other ways of measuring power.
- Presently, there is a strategic conflict between Iran and United Nations Security Council (UNSC) over Iran’s nuclear program. Iran has different options which it controls, including suspension of its uranium enrichment activities, expansion, or even escalation to war. To select its best option, Iran needs to predict the outcome of the negotiations which will be held in UNSC following its action. The most likely outcomes of these negotiations among the members of UNSC along with the associated likelihood measures can be identified, using the proposed methodology. These most likely outcomes of negotiations and the associated probability distribution estimated by the likelihood measures can be considered as input data for Iran’s decision problem.

Appendix A

Weights of the Decision Makers in the Epton Site Redevelopment Negotiations

As an exercise, we estimate each DM's weight in the decision making process which is important if the threshold of feasibility is something other than consensus. The procedure is summarized in Table A1. It is assumed that the following factors are the most important determinants of the capability of DMs in negotiations:

- Authority: Formal ability of a party to influence the decision making process.
- Motivation: A party's need to actively participate in the negotiations.
- Ownership: The owner of a property should have a veto over the redevelopment or the future use of the property.
- Investment: Financial capability of a party to invest in redevelopment.

Table A1: Estimation of DMs' Weights

DM	Authority 5	Motivation 4	Ownership 5	Investment 4	Overall Evaluation	Weight (Out of10)
LPH	2	6	10	6	108	8.6
City of Kitchener	7	9	3	10	126	10
University of Waterloo	2	10	0	8	82	6.5

The performance of each DM for each factor is quantified by a utility value between 0 and 10. The City of Kitchener possesses the highest authority among DMs due to its formal responsibilities and systematic connection to other governments. For example, it can complain about LPH to MOE if LPH does not appropriately remediate the contaminated Epton site (Witmer, 2008). The City of Kitchener has a strong motivation to encourage the School of Pharmacy because it will strengthen opportunities for commercial and municipal development. New investments in the city lead to more tax revenue. As the last column of Table A1 indicates, the City of Kitchener is the most capable DM, and the University of Waterloo the weakest, in negotiations over the redevelopment of the Epton site.

References

Ahmadov, A., *Dividing the Caspian: the primacy of national interests among littoral states in the Caspian basin*, Unpublished research, 2002.

Alcock, N., and Newcombe, A., The perception of national power. *Journal of Conflict Resolution*, 14:335-343. 1970.

Bassett, G. W., and Persky, J., "Robust voting," *Public Choice*, 99:299-310, 1999.

B.B.C News, Country Profiles, [Online], http://news.bbc.co.uk/2/hi/europe/country_profiles/1235976.stm (Accessed Sep. 8, 2007)

Brams, S.J., Kilgour, D.M., "Fallback Bargaining," *Group Decision and Negotiation* 10:287-316, 2001.

British Petroleum, Statistical Review of World Energy (2004), [Online], http://www.bp.com/productlanding.do?categoryId=91&contentId=7017990. (Accessed Oct 17, 2006)

Caspian Sea Region: Environmental Issues (2003), [Online], http://www.eia.doe.gov/emeu/cabs/caspenv.html. (Accessed June 5, 2006)

Charnes, A., Cooper, W.W., and Rhodes, E., Measuring the efficiency of decision making units, *European Journal of Operations Research*, 2:429-444. 1978.

Cook, W.D., Kress, M., "A Multiple-criterion composite index model for quantitative and qualitative data," *European Journal of Operational Research*; 78:367-379. 1994.

Dagan, N., Volji, O., “The bankruptcy problem: a cooperative approach,” *Mathematical Social Sciences,* 26:287-297, 1993.

Dahl, R., “The concept of power,” *Behavioural Science*, 2 (2): 201-215, 1957.

Dair, C. M., and Williams, K., “Sustainable land reuse: the influence of different stakeholders in achieving sustainable brownfield developments in England,” *Environment and Planning A*, Vol. 38, no. 7, 2006.

De, M., Hipel, K.W., Kilgour, D.M., “Algorithms for Hierarchical Power”, *Applied Mathematics and Computation,* 39, pp. 21-36, 1990.

De, M., Hipel, K.W., Kilgour, D.M., “Hierarchical Power in Personnel Negotiations”, *Group Decision and Negotiation,* 3, pp. 267-284, 1994.

Definitions of GNI on the Web [Online], http://www.google.ca/search?hl=en&defl=en&q=define:GNI&sa=X&oi=glossary_definition&ct=title (Accessed Oct. 25, 2007)

De Sousa, C.A., “Brownfield redevelopment versus Greenfield development: a private sector perspective on the costs and risks associated with brownfield redevelopment in the Greater Toronto Area,” *Journal of Environmental Planning Management,* Vol. 43, no. 6, pp. 831–853, 2000.

De Sousa, C.A., “Turning brownfields into green space in the City of Toronto,” Journal of Landscape and Urban Planning, Vol. 62, pp. 181-198, 2003.

Energy InformationAdministration, Official Energy Statistics from the US Government (2006) [Online], http://www.eia.doe.gov/emeu/cabs/Caspian/Background.html
(Accessed Oct 17, 2006)

EurasiaNet (2001) Tension seeps into Iranian – Russian relations. EurasiaNet, September 27, [Online], http://www.eurasianet.org/departments/recaps/articles/eva092701.shtml.
(Accessed May 20, 2002)

Fang, L., Hipel, K.W., Kilgour, D.M., *Interactive Decision Making: The Graph Model for Conflict Resolution*. New York: Wiley, 1993.

Fang, L., Hipel, K.W., Kilgour, D.M., and Peng, X., "A Decision Support System for Interactive Decision Making, Part 1: Model Formulation", *IEEE Transaction on Systems, Man and Cybernetics, Part C, SMC* – 33(1), PP. 42-55, 2003a.

Fang, L., Hipel, K.W., Kilgour, D.M., and Peng, X., "A Decision Support System for Interactive Decision Making, Part 2: Analysis and Output Interpretation", *IEEE Transaction on Systems, Man and Cybernetics, Part C, SMC* – 33(1), PP. 56-66. 2003b.

Fraser, N.M., and Hipel, K.W., *Conflict Analysis: Models and Resolutions*. New York: North Holland, 1984.

Fisher, R., Ury, W., and Patton, B., *Getting to yes: Negotiating agreement without giving in.* New York, NY: Penguin Books, 1991.

Gray, Peter A., Environmental Vice President of MTE Consultants Inc., Personal meeting on Monday, March 31, 2008 and Monday, August 11, 2008 in MTE office at 650 Riverbend Drive, Kitchener, Ontario, N2K 3S2.

Greenberg, M., Lee, C. and Powers, C., "Public Health and Brownfields: Reviving the Past to Protect the Future (editorial)," *American Journal of Public Health*, Vol. 88, no. 12, pp. 1759-1760, 1998.

Greenberg, M, Lawrie K, Solitaire, L., Duncan, L., "Brownfields, toads, and the struggle for neighbourhood redevelopment," Urban Affairs Review, Vol 35, no. 5, pp. 717 – 733. 2000.

Greenberg, M. and Lewis, M. J., “Brownfields Redevelopment, Preferences and Public Involvement: A Case Study of an Ethnically Mixed Neighbourhood,” *Urban Studies*, Vol. 37, no. 13, pp. 2501-2514. 2000.

Howard, N. *Paradoxes of Rationality: Theory of Metagames and Political Behavior*. Cambridge, Massachusetts: MIT Press, 1971.

Investopedia, What is GDP and why is it so important? [Online], http://www.investopedia.com/ask/answers/199.asp (Accessed Sep. 9, 2007)

Janusz, B., The Caspian Sea: legal status and regime problems, StiftungWissenschaft, Russia and Eurasia programme, 2005. [Online], http://www.chathamhouse.org.uk/pdf/research/rep/BP0805caspian.pdf. (Accessed Oct 17, 2006)

Kaliyeva, D., The geopolitical situation in the Caspian Sea, UNISCI Discussion Papers, Kazakhstan Institute for Strategic Studies, 2004.

Kazakhstan Special Weapons [Online], http://www.fas.org/nuke/guide/kazakhstan/index.html (Accessed Oct. 25, 2007)

Kekic, L., “The Economist Intelligence Unit, Index of democracy”, Country forecasting services, Economist Intelligence Unit, [Online], http://www.economist.com/media/pdf/DEMOCRACY_INDEX_2007_v3.pdf (Accessed Oct. 31, 2007)

Kersten, G. E. "The science and engineering of e-negotiation: Review of the emerging field," InterNeg, Ottawa INR05/02, 2002.

Larson, Lee E., President of LP Holdings Inc., Verbal Information obtained from Mr. Larson at a meeting held from 2 to 5 p.m on Tuesday, September 30, 2008, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.

Larson, Lee E., " The Epton Chronicles", unpublished manuscript, Ohio, USA, 2008.

List of countries by GDP, 2006 List by the World Bank [Online], http://en.wikipedia.org/wiki/List_of_countries_by_GDP_%28nominal%29 (Accessed Sep. 14, 2007)

List of countries by military expenditures [Online], http://en.wikipedia.org/wiki/List_of_countries_by_military_expenditures (Accessed Sep. 8, 2007)

List of countries by size of armed forces [Online], http://en.wikipedia.org/wiki/List_of_countries_by_size_of_armed_forces (Accessed Sep. 8, 2007)

List of states with nuclear weapons [Online], http://en.wikipedia.org/wiki/List_of_states_with_nuclear_weapons#Former_Soviet_countries (Accessed Oct. 25, 2007)

Maleki, A., Iran's changing perspectives and policies on the Caspian Sea, Interview with Abbas Maleki on 22 Mar 2001, [Online], http://www.netnative.com/news/01/mar/1112.html. (Accessed Oct 17, 2006)

Merlin, V., Sanver, I.O., and Sanver, M.R., Properties of majoritarian compromise, efficient compromise, and related compromise rules, Preliminary version, 2006.

Muresan, L., Non-military risks to the international security in central and Eastern Europe after the Cold War, the partnership for future for a sustainable security system. Bucharest, Romania, 1998.

Nash, J. F., Equilibrium Points in n-Person Games, *Proceedings of National Academy of Sciences*, 36, 48-49, 1950.

Nash, J. F., "Noncooperative Games," *Annals of Mathematics* 54(2), 286-295. 1951.

Nurmi, H., *Voting paradoxes and how to deal with them.* Springer Verlag, Berlin, 1999.

Oracle8i Java Stored Procedures Developer's Guide, "Drawing the Entity-Relationship Diagram", [Online], http://lbdwww.epfl.ch/f/teaching/courses/oracle8i/java.815/a64686/05_dev1.htm January 14, 2008]

Rabinowitz, P. D.,.Yusifuv, M. Z, Arnoldi, J., and Hakim, E., "Geology, Oil and Gas Potential, Pipelines, and the Geopolitics of the Caspian Region," *Ocean Development & International Law*, 35:19–40, 2004.

Roberts, K., *Social choice theory and the informational basis approach*. Nuffield College, Oxford, 2006.

Sage, A. P., *Decision Support Systems Engineering*, New York: Wiley. 1991.

Schelling, T.C., *The Strategy of Conflict,* Harvard University Press, Cambridge, MA. 1960.

Sertel, M.R., Yilmaz, B., "The majoritarian compromise is majoritarian optimal and subgame perfect implementable," *Social Choice and Welfare,* 16:615-627, 1999.

Simon, H., Notes on the observation and measurement of power, *Journal of Politics*, 153: 500-516, 1953.

Stoll, R., and Ward, M., Power *in World Politics*, Lynn Rienner, Boulder, CO. 1989.
Tawney, R.H., *Equality*, London: Unwin. 1931/1952.

The Community Environmental Resource Program (CERP), [Online] http://stlcin.missouri.org/cerp/brownfields/definition.cfm (Accessed October 10, 2008)

The World Bank - Data for the year 2006. [Online], http://www.worldbank.org/ (Accessed July 1, 2007)

Tibaut, J.W., and Kelley, H.H., *The Social Psychology of Groups*, New York: John Wiley & Sons, Inc. 1959.

Trade Competitiveness Map [Online], http://www.intracen.org/appli1/TradeCom/TP_EP_CI.aspx?RP=031&YR=2005 (Accessed Sep. 9, 2007)

US Aid Budget, [Online], http://www.usaid.gov/policy/budget/cbj2006/ee/kz.html (Accessed Oct. 25, 2007)

US Energy Information Administration, U.S. Natural gas prices. [Online], http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm .(Accessed Oct 17, 2006)

USEPA. Brownfields Economic Redevelopment Initiative, Washington, DC: US Environmental Protection Agency, Solid Waste and Emergency Response. 1997.

Witt, R., “A sea or a lake? The Caspian’s long odyssey” Central Asian Survey 19(2):189–221, 2000.

Yahoo! Canada Answers [Online], http://ca.answers.yahoo.com/answers2/frontend.php/question?qid=20070813050514AAzQPlz (Accessed Oct. 25, 2007)

Young, P., Optimal voting rules. *The Journal of Economic Perspectives* 9(1):51-64, 1995

Witmer, Jim, Director of Operations, City of Kitchener, Personal meetings held on Wednesday, October 1, 2008, Tuesday, October 7, 2008, and Thursday, October 16, 2008 in City Hall, 200 King Street West Kitchener, Ontario, Canada, N2G 4G7.

Zartman, W., and Rubin, J., *Power and negotiation,* Ann Arbor, Michigan: The University of Michigan Press, 2003.

Zartman, I.W., “The political analysis of negotiation: How who gets to what and when,” *World Politics*, 26(3):385-399, 1974.