Negotiations Support System with Third Party Intervention

by

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Abstract

Conflict analysis algorithms usually provide forecasting information according to the conflict parameters. However, values of these parameters may be subjective or change unexpectedly, resulting in a different outcome than the one initially predicted. What if there is an algorithm that can generate scenarios of how the conflict is likely to evolve? Furthermore, what if the tool can allow the analyst to specify a desired resolution and understand all scenarios that can achieve or avoid that specific resolution? The framework of the Graph Model for Conflict Resolution (GMCR) can be used to predict the likely outcome of a strategic conflict. However, understanding how a specific outcome can be reached within a negotiation is a challenge that is not addressed in GMCR.

In this thesis, a formal methodology to provide an informed collective negotiation support is introduced. This new methodology is generated by reverse engineering some GMCR procedures and is therefore called "Inverse GMCR". The essence of Inverse GMCR is to determine how a strategic conflict should be ideally resolved, and inform the mediators of the strategies to negotiate and achieve this resolution.

Pattern recognition and inverse calculations are used to generate different strategies that will allow mediators to negotiate a desired resolution. Mediation, or third party intervention, is highly enhanced by utilizing the insightful information provided by the negotiation support system. In order to efficiently compute results and generate strategies, an advanced comprehensive decision support system (DSS) is developed. This system, called GMCR+, has the capability to model and analyze GMCR models in addition to negotiation problems. Furthermore, GMCR+ introduces advanced capabilities that were

not available in previous DSS such as graphing capabilities, status quo analysis, and results reporting and narration.

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Chapter 1

Introduction

A dispute arises when two or more individuals or groups have conflicting interests over economic relations, international trade, environmental management, interpersonal relationships, and many other endeavors. In fact, for society to be sustainable, various stakeholders of scarce resources and competitors in industrial development have to reach appropriate compromises. When several parties are involved, each with an interest in the outcome of the conflict, decision makers (DMs) have to select between options under their control to determine the outcome. Although each DM has some power over the outcome, no single DM has full control. Therefore, a strategic conflict resolution and analysis methodology is employed to determine potential strategic results. Earlier methodologies of modeling and analyzing conflict include metagame analysis Howard (1971, 1987), conflict analysis Fraser and Hipel (1984), drama theory Howard (1994a,b), and hypergame analysis to model misperceptions Bennett (1980); Wang et al. (1988). The Graph Model for Conflict Resolution (GMCR) constitutes an improvement over earlier methodologies in its flexibility for the

systematic resolution of real-world strategic conflicts Kilgour and Hipel (2005). The application of GMCR involves two main stages: modeling and analysis, as will be outlined in Section 3 Hipel et al. (1990). The modeling stage includes determining the DMs, all possible options, and DMs' preferences. The analysis stage is responsible for determining the possible equilibria or outcomes of the conflict. Practical application of conflict resolution methodologies can require cumbersome data analysis and iteration. This warrants implementation of a computerized DSS to expedite calculation of strategic results for interpretation by analysts.

1.1 Research Motivation

Conflicts are the most costly and dangerous of all social processes Bercovitch and Gartner (2009). The development of an approach to model third party intervention in conflicts will address the most crucial element of international relations, which is conflict, and the most influential component of a conflict, which is mediation. Surveying the literature, as will be outlined in depth in Chapter 2, reveals the need for a comprehensive approach to model and analyze the intervention of a third party in conflict. Many studies on mediation address specific conflicts or sets of conflicts but end up using regression analysis, which may be unreliable and difficult to apply in reality.

About 70 percent of all international conflicts since 1945 have involved mediation (Bercovitch and Gartner, 2006). Although mediation can be defined in many ways, the definition used here is that mediation is a "process of conflict management, related to but

distinct from the parties' own efforts, whereby the disputing parties or their representatives seek the assistance, or accept an offer of help from an individual, group, state or organization to change, affect or influence their perceptions or behavior, without resorting to physical force, or invoking the authority of the law" (Bercovitch and Rubin, 1992). This definition captures aspects related to third party intervention. A related concept is arbitration where a third party could arbitrate a disputant to accept a resolution due to third party power of influence.

A number of water conflicts involving a third party in the Middle East were studied recently. The studies emphasize the effects of third party intervention in bringing about a resolution (Hipel et al., 2014). The regular GMCR was used to model and analyze the conflicts before and after third party intervention. The yielded outcomes were significantly different. The applications provided the motivation to seek a more generalized approach to formally model negotiation and third party intervention within the framework of GMCR.

1.2 Research Objectives

There are two main objectives of this research: the first is to develop a negotiation modeling approach to assist in conflict mediation; the second is to develop a comprehensive DSS to allow practical application of different modeling methodologies related to GMCR, including the new negotiation model.

The specific goals of this research and their intended results are outlined as follows:

1. Reverse engineer the pre-existing GMCR to develop a new approach called "Inverse

GMCR"

- To allow mediators to understand how a desired resolution can be achieved and suggest relevant strategies to the DMs.
- To overcome the documented challenges in modeling conflicts in standard GMCR such as determining preference ranking (see challenge 4 in (Hipel, 2011)).
- To require minimal information to model conflicts.

2. Propose new stability definitions for "Inverse GMCR".

- To allow formal and systematic modeling of negotiation problems.
- To allow the new methodology to be efficiently programmed.

3. Develop a comprehensive DSS with user-friendly advanced features.

- To ease application of the methodology by both professionals and practitioners.
- To overcome all limitations of previous DSSs.
- To provide analysts with insightful information using graphs, tables, and narrated results.
- To present interactive post-analysis tools such as equilibria categorization, coalition analysis, and status quo analysis.
- To accompany future advancements of GMCR by having a modular design.

4. Diverse real-world applications

- To illustrate the value of "Inverse GMCR" in a variety of application domains.

- To validate and verify the new DSS using documented real-world applications in literature.

1.3 Thesis Organization

The following diagram in Figure 1.1 illustrates the organization of this thesis with key points of each chapter.

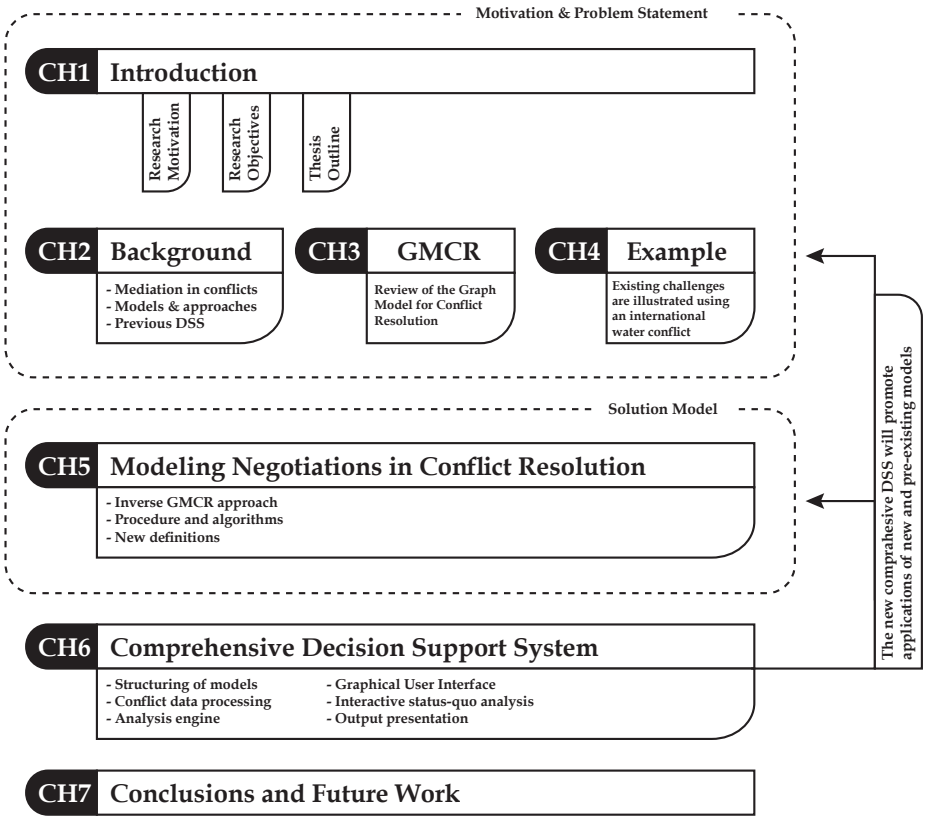

Figure 1.1: Thesis Organization

Chapter 2

Background and Literature Review

2.1 Third Party in Conflicts

Of the many approaches to the study of third party intervention, three are prominent in the literature (Bercovitch and Gartner, 2009) :

1. Individual case studies: these lines of research, such as will be mentioned in the literature review in Chapter 2, analyze and explore specific conflicts in detail. Although this kind of analysis provides significant insights about a particular conflict, it may lack the ability to be generalized and accommodate other conflicts.

2. Experimental approaches: these approaches are laboratory experiments where variables are controlled by researchers in an artificial setting (Rubin, 1980; Carnevale and De Dreu, 2005)

3. Large scale systematic studies: these studies analyze data representing many conflicts and use criteria to identify factors and relationships affecting the conflicts and their outcomes. It gives a more generalized understanding of conflict management.

The methodology presented in this proposal borrows features from the last two approaches. It has controlled variables, yet it is applicable to real conflicts. This methodology is a generalized approach on its basic level, but applies to specific conflicts yielding profound insights.

Research into the impact of a third party in conflict resolution is reviewed in this section. The first subsection discusses the different types of conflict and the impact of third party intervention on them. Subsections 2.1.2 and 2.1.3 discuss the possible roles of a third party, in addition to other issues. Finally, subsection 2.1.4 reviews the existing modeling approaches for third party intervention.

2.1.1 Overview and Conflict Types

Third party intervention in conflicts has been widely investigated from different perspectives. Most of the research lies within the areas of international relations and political sciences. These studies address issues regarding mediation including methods of intervention (Fisher, 2001), strategies for intervention (Prein, 1987), and conditions for successful intervention (Regan, 1996). Conflicts can be classified in a wide variety of ways. In the world of mediation, the differentiation between intrastate and interstate conflicts is usually clear. A study by Regan (1996) focuses on success conditions for third party interventions

in intrastate conflicts. Another classification by Bercovitch and Gartner (2006) differentiates between high intensity conflicts and low intensity conflicts. Another categorization for conflicts is based on cause, including ethnic, religious, or ideological (Regan, 1996). The size of the conflict, or the number of parties involved provides one more means for classification (Jehn, 1997)

2.1.2 Third Party Roles

A third party can assume different roles in a conflict. Sakamoto et al. (2005) suggested three roles a third party can undertake in a conflict. These roles are commonly assumed when the mediator is not an actual party in the conflict, but is motivated to bring about a more preferred resolution. The suggested three roles are arbitrator, coordinator, and donor. The authors explain each role within a conflict. A third party is an arbitrator if it has the power to restrict or force a stakeholder to accept a certain resolution. If a third party can alter stakeholders' preferences, then it is either a coordinator or a donor. The difference between the last two roles depends on the time of influence of the third party. A coordinator influences the stakeholder to change preferences immediately, while a donor works on the long term (Sakamoto et al., 2005). On the other hand, Raiffa (1982) classifies third parties as facilitators, mediators, arbitrators, or rule manipulators. Another study suggests mediators can be individuals, regional organizations, states, or international institutions (Bercovitch and Schneider, 2000; Bercovitch and Gartner, 2006). The latter study surveyed 2,354 international conflicts involving mediation since 1945 in order to analyze them and assess various general hypotheses. Table 2.1 summarizes their dataset.

Some of their hypotheses will be outlined in subsection 2.1.4 of this proposal.

Category	Frequency	Percent (within category)
Mediators		
Individual	106	4.50
Regional	362	15.38
International	792	33.64
State	1,094	46.47
Strategies		
Communications	1,235	52.46
Procedural	434	18.44
Directive	685	29.10
Mediation History		
None	137	5.82
Offered Only	129	5.48
Fail	1,182	50.21
Ceasefire	228	9.69
Partial Settlement	579	24.60
Full Settlement	99	4.21
Outcome		
Failure	1,310	55.65
Ceasefire	234	9.94
Partial Settlement	657	27.91
Full Settlement	153	6.50
Total	2,354	

Table 2.1: Dataset Summary (Adopted from Bercovitch and Gartner (2006)

2.1.3 Miscellaneous issues

The literature is full of issues and factors affecting third party intervention. For example, factors affecting the process of intervention is that a mediator can act formally or informally, be invited to the conflict or not, intervene independently or on behalf of an organization, have interest in the outcome or in the process of intervention, be inclined toward one party

or the other, and be consultative or directive in the intervention (Lewicki et al., 1992). Furthermore, mediation history can also have an effect on a new intervention attempt (Bercovitch and Gartner, 2006). A study by Carnevale and De Dreu (2005) addresses the element of time. They found that time pressure affects the mediator to be aggressive in intervening and to use pressuring tactics. Other studies on the effectiveness of third party intervention suggest factors that influence the success of specific situations. For instance, if an uninvited third party intervenes, Murray (1983) specifies three important factors for mediation efficiency: dispute maturity, disputants' relationship, and intervention timing. Other issues raised by different researchers include culture, power asymmetries, conflict ripeness, number of third parties, third party authority, bias, and consistency (Fisher, 2001).

Another aspect of mediation is strategy. The range of strategies a mediator can undertake is immense. Regan (1996) suggests three basic strategies of intervention within intrastate conflicts: military, economic, or mixed. Young (1972) discusses four intermediary functions: informational, tactical, supervisory, and re-conceptualization. In another study on successful mediation, Bercovitch et al. (1991) outline different strategies that can be adopted by a third party: conciliation-facilitation, procedural, directive, substantive, and supervisory. The authors explain each of these strategies and assess their impact based on a range of historical conflicts. While these studies emphasize specific strategies, other approaches provide a more generic context, referred to as intervention styles. For instance, Bartunek et al. (1975) organize intervention techniques into two broad styles: content form and process form. Another wide classification is that of Touval and Zartman, who catego-

rize all intervention approaches as communication, formulation, or manipulation strategies (Bercovitch and Wells, 1993). Bercovitch and Gartner (2006) suggest that all strategies can be grouped into communication, procedural, or directive strategies.

2.1.4 Third Party Modeling

Many studies in the literature tackle third party intervention in the context of a specific historical conflict or set of conflicts such as the work by Regan (1996); Bercovitch et al. (1991); Dixon (1996). For instance, the research by Regan (1996) on success conditions for third party interventions focuses only on intrastate conflicts and analyzes the conflicts occurred during the period between 1944 to 1994 (Table 2.2). The author suggests a regression model based on the dataset he gathered as illustrated in Fig 2.1. The author emphasizes three intrastate conflict types: ethnic, religious, and ideological. Moreover, the regression model took into account other factors affecting the intervention such as the type of conflict, number of causalities, intervention type, and intervention target. Other attempts to formally model third party intervention based on particular conflicts include the research by Carment and James (1996); Hipel et al. (2014). Although most third party modeling based on historical conflicts use regression analysis (Regan, 1996; Dixon, 1996), the latter two studies use game theory based models. In addition, Fisher (2001); Lewicki et al. (1992) discuss different conceptual and descriptive models for third party intervention. Lastly, a standard conflict model of third party intervention is suggested by Siqueira (2003).

Results of Logit Regression on the Success or Failure of Intervention

Variable	*Estimated Coefficient*	SE	T-*Ratio*
Conflict type	–.40	.34	–1.17
Casualties	$-.70 \times 10^{-6}$	$.13 \times 10^{-5}$	–.54
Type of intervention	1.26	.59	2.13
Target of intervention	–.12	.03	–3.36
Major Power × Type	–.07	.02	–2.91
Major Power × Target	.12	.03	3.25
Constant	.89	.54	1.63

Log likelihood (0) = –117.71
Log likelihood function = –107.95
Likelihood ratio test = 19.50 with 6 *df*

	Predicted Outcomes	
Actual Outcomes	*Success*	*Failure*
Success	11	7
Failure	48	124

NOTE: Number of correct predictions = 135; percentage of correct predictions = 71%.

Figure 2.1: A snapshot of the regression model by Regan (1996) with the results applied to the study dataset

Conflict	*Type*	*Dates*	*Casualties*	*Interventions*	*Type of Intervention*	*Target of Intervention*	*Success*
Republic of Vietnam	Ideological	1960-1965	300,000	U.S.	Mixed	Government	No
				DRV Vietnam	Military	Opposition	No
Zairian Civil War	Ethnic	1960-1965	300,000	Belgium	Military	Opposition	No
				United Nations	Mixed	Government	Yes
				Algeria	Military	Opposition	No
				Egypt	Military	Opposition	No
				Belgium	Mixed	Government	Yes
Ogaden Conflict I	Ethnic	1960-1964	300	Somalia	Military	Government	No
Laos I	Ideological	1960-1962	30,000	U.S.	Mixed	Opposition	Yes
				U.S.S.R.	Military	Opposition	Yes
				RVN Vietnam	Military	Opposition	Yes
Iraq (Kurdish Rebellion)	Ethnic	1961-1966	5,000	Syria	Military	Government	No
Eritrean War	Ethnic	1962-1991	45,000	Cuba	Military	Opposition	No
				U.S.S.R.	Military	Opposition	No
				U.S.	Mixed	Government	No
				Cuba	Military	Government	No
				U.S.S.R.	Mixed	Government	No
				Sudan	Military	Opposition	No
Arab Republic of Yemen	Ideological	1962-1964	100,000	Egypt	Military	Government	Yes
				Saudi Arabia	Mixed	Opposition	No
				Jordan	Mixed	Opposition	No
Laos II	Ideological	1963-1973	18,000	U.S.	Mixed	Government	No
				DRV Vietnam	Economic	Opposition	No
				France	Military	Government	No
Sudanese Civil War	Religious	1963-1972	200,000	Belgium	Military	Government	No
Cyprus	Ethnic	1963-1964	3,000	U.K.	Military	Neutral	No
				Greece	Military	Government	No
				Turkey	Military	Opposition	No
				United Nations	Military	Neutral	Yes
Chad Civil War I	Ethnic	1965-1972	1,500	France	Military	Government	No
				Libya	Military	Opposition	No
Dominican Revolt	Ideological	1965	1,000	U.S.	Military	Government	Yes
				Honduras	Military	Government	Yes
Thai Communist Insurgency	Ideological	1965-1985	10,000	U.S.	Mixed	Government	No
				China	Military	Opposition	No
				Malaysia	Military	Government	No
Guatemalan Communist Insurgency I	Ideological	1966-1972	45,500	U.S.	Mixed	Government	No
Congo, Kisanguni Mutiny	Ideological	1967	20,000	U.S.	Military	Government	Yes
				Belgium	Mixed	Opposition	No
Burmese Communist Insurgency I	Ideological	1968-1980	1,500	China	Military	Opposition	No
Oman, Dhofar Rebellion	Ethnic	1970-1975	2,000	U.K.	Military	Government	Yes
				Iran	Military	Government	Yes
				Jordan	Military	Government	Yes
				YPR Yemen	Military	Opposition	No
Cambodia	Ideological	1970-1975	150,000	RVN Vietnam	Military	Government	No
				U.S.	Military	Government	No
				DRV Vietnam	Military	Opposition	Yes
Northern Ireland	Religious	1968-1994	3,000	Libya	Military	Opposition	No

Table 2.2: A dataset segment of the Intrastate Conflicts used in Regan's study (Table adopted from Regan (1996)

A study by Sakamoto et al. (2005) illustrates an approach to incorporate third party intervention in conflict modeling using GMCR. The research suggests three roles a third party can play (explained in subsection 2.1.2 of this report) and developed a conflict management procedure for them. Fig 2.2 below illustrates the authors' conflict management approach with the intervention of a third party.

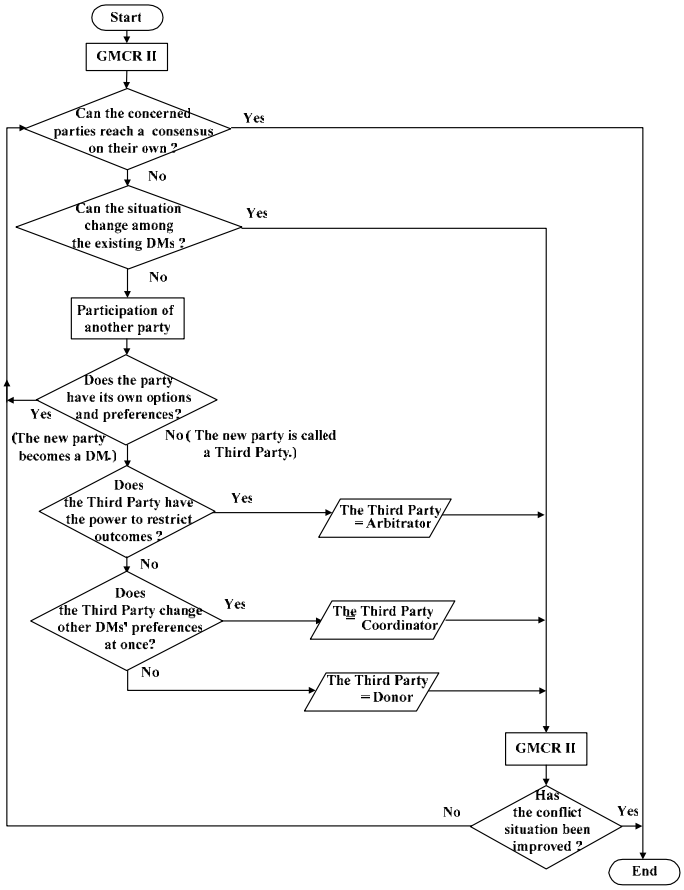

Figure 2.2: Chart developed by Sakamoto et al. (2005) to illustrate conflict management with a third party

A comprehensive study by Bercovitch and Gartner (2006) investigates in depth the success factors of third party intervention. The authors focus on mediators' identities, strategies, and mediation history to predict the outcome of mediation. According to the authors, mediators can be classified according to four categories: individuals, states, regional organizations, and international institutions. After discussing each category, the authors claim that in low intensity conflicts, state and regional mediators are more likely to be successful. However, they are less likely to be successful in high intensity conflicts. International mediators are likely to be effective in high intensity conflicts and individuals are unlikely to be successful in all conflict types. On the other hand, the authors suggest that mediation strategies include communication-facilitation, procedural, and directive strategies. Similarly, the authors make some hypotheses after explaining each of the strategies. They claim that directive strategies are most likely to be successful in high intensity conflicts but not in low intensity conflicts. Procedural strategies are mostly successful in low intensity conflicts. Tables 2.3 and 2.4 are summaries derived from the research hypotheses in the study.

Conflict Type	**Identity**			
	Individuals	***States***	***Regional Organizations***	***International Institutions***
High Intesity	Unlikely	Less likely	Less likely	Likely
Low Intensity	Unlikely	Likely	Likely	Likely

Table 2.3: Mediator type and likelihood to be successful

Conflict Type	Strategy		
	Directive	***Procedural***	***Communication-Facilitation***
High Intesity	Likely	Unlikely	Passive
Low Intensity	Unlikely	Likely	Passive

Table 2.4: Mediator strategy and likelihood to be successful

2.2 Models and Approaches

In order to formally model third party intervention in conflicts, three areas will be investigated, as follows:

1. Inverse approach to conflict resolution: A modeling technique that will allow mediators to choose a desired outcome as equilibrium, and work backwards to achieve it.

2. Inverse status quo analysis: An extension to the previous area that determines whether the desired equilibrium is reachable from the original state.

3. Third party prediction: A tool to analyze conflicts inviting mediation and give insight as to which role a mediator should play to resolve the conflict.

2.3 Chapter Summary

Chapter 3

The Graph Model for Conflict Resolution (GMCR)

The Graph Model for Conflict Resolution (GMCR) has been developed and expanded since the mid-1980s (Kilgour and Hipel, 2005). GMCR is a tool to strategically analyze moves and counter moves in a conflict in order to predict the most likely outcome.

3.1 Procedure

The basic procedure of GMCR involves two main stages: modeling and analysis. In the modeling stage, the user identifies the conflict parameters which include:

- Decision makers (DMs)
- Options for each DM

- Infeasible states (such as mutually exclusive situations)
- Allowable transitions
- Relative preferences

After identifying the conflict parameters, the user will analyze the conflict from each DM's perspective to determine the likely final resolution. This stage include:

- Determining individual stability (i.e. for each DM)
- Overall equilibria
- Sensitivity analysis

The following diagram in Figure 3.1 illustrates the basic GMCR procedure (The diagram is adapted from Fang et al. (1993)).

3.2 Notation and Definitions

The graph model representing a real world conflict includes DMs, options, and preferences. These parameters are formally defined as follows:

Definition 3.2.1. Let $N = \{1, 2, \ldots, n\}$ represent the set of DMs, for each DM $i \in N$, the set O_i is i's options or strategy set and $S = \{s_1, s_2, ..., s_m\}$ represent the set of feasible states.

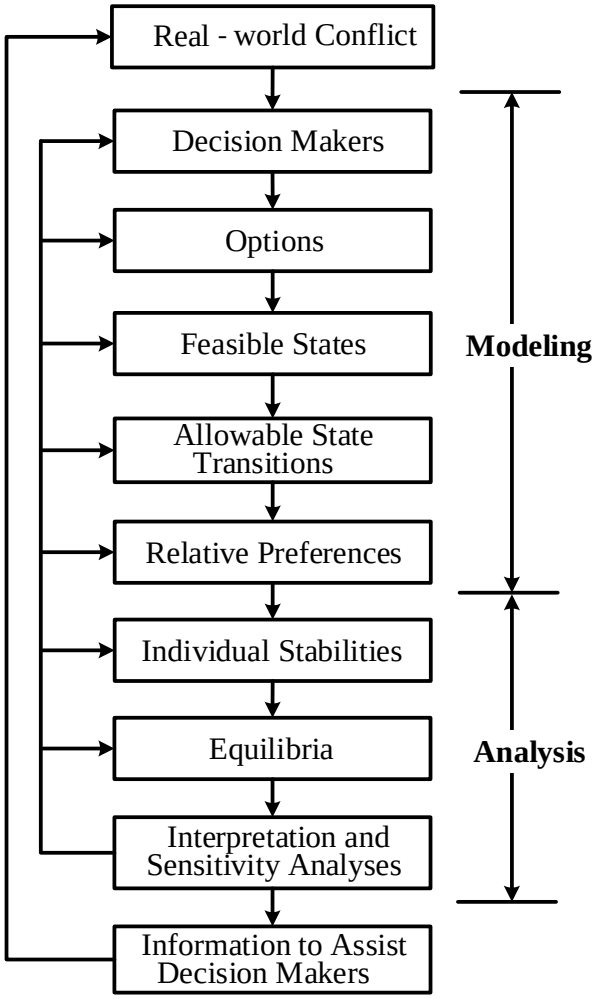

Figure 3.1: The basic procedure of GMCR in a real world conflict (adapted from Fang et al. (1993))

The set of possible states in a conflict is represented by the expression 2^o where o is the total number of options in a conflict. Some of the possible states may be infeasible such as mutually exclusive options, at least one type of options, or dependent options. In a conflict model, a set of feasible states is defined.

Definition 3.2.2. Let $S = \{s_1, s_2, ..., s_m\}$ represent the set of feasible states in a conflict.

For each DM $i \in N$, a set of directed graphs $D_i = (S, A_i)$ can be used to model the conflict.

The feasible states of a conflict are represented by vertices in the graph model. In each graph, an arc A_i exists between states s_a and $s_b \in S$ if DM i can move unilaterally in one step between the two states. It is called a *directed* graph because the arc has an orientation which can be one way (irreversible move) or two ways (reversible move).

Definition 3.2.3. Let $i \in N$ and $s \in S$. The reachable list of DM i from state $s \in S$ is defined as:

$$R_i(s) = \{s_a \in S \quad : \quad (s, s_a) \in A_i\}$$

The move in one step by DM i from a state s_a to a state in the reachable list $\{s_b \in S\}$ is called a unilateral move (UM).

The preference information of DM i is a binary relation $\{\succ_i, \sim_i\}$ over S, where $s_a \succ_i s_b$ means that DM i prefers s_a to s_b and $s_a \sim_i s_b$ means that DM i is indifferent between states s_a and s_b. The binary relation $\{\succ_i, \sim_i\}$ is considered complete.

Definition 3.2.4. Let $i \in N$ and $s \in S$. The unilateral improvement list for DM i from state $s \in S$ is defined as:

$$R_i^+(s) = \{s_a \in R_i(s) \quad : \quad s_a \succ_i s\}.$$

The move in one step by DM i from a state s_a to a state in the unilateral improvement list $\{s_b \in S\}$ is called a unilateral improvement (UI).

3.3 Stability Definitions and Solution Concepts

The main goal of the graph model for conflict resolution is to predict the stability of each state for each DM. There are four basic solution concepts according to which a state can be assessed for stability: Nash stability (sometimes called rationality), sequential stability (SEQ), general metarationality (GMR), and symmetric metarationality (SMR).

The solution concepts describe how a DM is motivated to make moves and counter moves. These concepts (or behavior patterns) determine whether a specific state will be terminal or a DM will be motivated to deviate to another state. Different DMs may have different behavior patterns based on different factors. These factors include risk, foresight, and available information. Behavioral characteristics according to the different solution concepts are given in Table 3.1 below.

Definition 3.3.1. (Nash Stability) Let $i \in N$ and $s \in S$. State s is *Nash stable* for DM i *iff* $R_i^+(s) = \phi$.

Definition 3.3.2. (Sequential Stability) Let $i \in N$ and $s \in S$. State $s \in S$ is *sequentially stable* (*SEQ*) for DM i *iff* for every $s_1 \in R_i^+(s)$ there exists at least one $s_2 \in R_{N-i}^+(s_1)$ such that $s_2 \precsim_i s$.

Definition 3.3.3. (General Metarationality) Let $i \in N$ and $s \in S$. State $s \in S$ is *general metarational* (*GMR*) for DM i *iff* for every $s_1 \in R_i^+(s)$ there exists an $s_2 \in R_{N-i}(s_1)$ such that $s_2 \precsim_i s$.

Definition 3.3.4. (Symmetric Metarationality) Let $i \in N$ and $s \in S$. State $s \in S$ is *symmetric metarational* (*SMR*) for DM i *iff* for every $s_1 \in R_i^+(s)$ there exists an $s_2 \in$

$R_{N-i}(s_1)$ such that $s_2 \precsim_i s$ and $s_3 \precsim_i s$ for all $s_3 \in R_k(s_2)$.

Solution Concepts	**Stability Descriptions**	**Foresight**	**Knowledge of Preferences**	**Disimprovement**	**Strategic Risk**
Nash stability (**R**)	Focal DM (decision maker) cannot move unilaterally to a more preferred state.	Low	Own	Never	Ignores risk
General Metarational (**GMR**)	All focal DM's unilateral improvements are sanctioned by subsequent unilateral moves by others	Medium	Own	By opponents	Avoids risk; conservative
Symmetric Metarational (**SMR**)	All focal DM's unilateral improvements are sanctioned, even after response by the focal DM.	Medium	Own	By opponents	
Sequential Stability (**SEQ**)	All focal DM's unilateral improvements are sanctioned by subsequent unilateral improvements by others.	Medium	All	Never	Takes some risks; satisfices

Table 3.1: Behavioral characteristics describing different solution concepts

Definition 3.3.5. (Equilibrium) Let $i \in N$ and $s \in S$. State $s \in S$ is called *equilibrium* (E) *iff* it is stable for every DM.

Sometimes the graph model for conflict resolution is referred to as a 3-tuple or triplet $G = \langle N, S, (\succ_i, \sim_i)_{i \in N} \rangle$ where N is the list of DMs $N = \{1, \ldots, n\}$, S is the set of feasible states $S = \{1, \ldots, m\}$, and $(\succ_i, \sim_i)$ is the binary relation DM i has on S. Consequently, $Nash(G) = \{\ s \in S\ :\ s\ $ is a Nash Equilibrium of $G\}$. More explicitly,

$$Nash(N, S, (\succ_i, \sim_i)_{i \in N}) = \{\ s \in S\ :\ s\ \text{ is Nash stable for all } i \in N \text{ in } \langle N, S, (\succ_i, \sim_i)_{i \in N} \rangle\}$$

and similarly for SEQ, GMR, and SMR.

3.4 Follow-Up Analysis

To take the basic analysis further, a number of follow-up analyses may be undertaken to test the reliability of the predicted outcomes and whether they are achievable from the status quo or not.

3.4.1 Sensitivity Analysis

Since many conflict parameters are subjective, it may be essential to test different scenarios in order to determine the robustness of the conflict model. Sensitivity analysis also points out how different parameters can influence the stability results. The most common type of sensitivity analysis is the change of preference since it is the most difficult parameter to obtain and determine. Other sensitivity analysis types include:

- Adding or combining DMs
- Change of options (adding, removing, or modifying)
- Changing moves reversibility
- Coalition analysis
- Modeling misunderstandings (hypergames)
- Examining other patterns of human behavior

3.4.2 Status Quo analysis

Every real world conflict has a starting point from which the conflict evolves. This point or state is called *status quo* (Fang et al., 1993). Depending on the status quo, a potential equilibrium may or may not be reached. Li et al. (2004b, 2005) developed algorithms and formal definitions to inspect the attainability of a potential resolution (*equilibrium*) from a certain state (*status quo*).

3.5 Decision Support System for GMCR

3.5.1 Review of Existing Decision Support Systems

3.6 Chapter Summary

Chapter 4

Strategic Investigations of Water Conflicts in the Middle East

The arid nature of the Middle East environment causes continuously escalating conflicts among the countries of the region. Conflicts arise as water resources dwindle due to increased industrial and agricultural projects and population growth. The main renewable sources of freshwater in the region are rivers. Like all water resources, they are replenished by their hydrological cycle, with renewal rates varying from days to centuries. The rate of renewal for Middle Eastern rivers is decreasing due to population growth and the increasingly arid conditions of the region. At 2,700 km, the Euphrates is the longest and arguably most important river in the Middle East (Southwest Asia) (Kolars and Mitchell, 1991). The Euphrates originates in eastern Anatolia in Turkey and flows through Syria and finally Iraq, where it joins the Tigris River. Conflicts regarding the river became se-

rious during the 1960s, when Turkey began building dams on the Euphrates to generate electricity and increase the availability of irrigation water in Southeast Turkey (Akanda et al., 2007). As a result of external mediation, war was narrowly avoided twice, in 1975 and 1998 (Akanda et al., 2007).

Water conflicts have been widely investigated during the last decade (Dinar, 2004) and different approaches taken to model them (Madani, 2010). For instance, the Waiahole Water Project conflict, in the American state of Hawaii, has been modeled and analyzed using the Graph Model for Conflict Resolution (Gopalakrishnan et al., 2005), and a status quo analysis of the Flathead River conflict involving the United States and Canada was examined using the same methodology (Li et al., 2004c). Other modeling approaches used for studying water conflicts include Alternative Dispute Resolution (ADR) (Wolf, 2000), Shared Vision Modeling (Lund and Palmer, 1997), and Adjusted Winner (AW) mechanism (Massoud, 2000).

The aim of this chapter is to examine in depth the main conflicts that have occurred in the past along the Euphrates and to model them using the GMCR methodology (Kilgour et al., 1987; Fang et al., 1993) as implemented by the decision support system, GMCR II (Hipel et al., 1997; Fang et al., 2003a,b). Time periods of interest for this analysis are 1975, 1990, and 1998, when the conflict escalated to the near outbreak of a full scale war. Accordingly, the historical backgrounds underlying the disputes at these three points in time are described in the next section. Subsequently, modeling and stability analyses are carried out for these three conflicts, followed by a summary of strategic insights that are garnered.

4.1 Background

As explained in the next three subsections, the interconnected conflicts of 1975, 1990, and 1998 took place dynamically over time. Therefore, systematically investigating these disputes together enhances the appropriateness of the analyses and furnishes more meaningful insights.

4.1.1 The conflict in 1975

In 1966, Turkey started the construction of the Keban Dam, which is a hydroelectric dam on the Euphrates River (Fig 4.1). After the construction was finished in 1974, Turkey started the filling of the Keban Reservoir. During the flooding, Turkey maintained a 450 m^3/s discharge of the Euphrates to the two downstream countries consisting of Syria and Iraq. This rate was agreed upon by both countries through the United States Agency for International Development (USAID), which was financing the project (Inan, 2000). However, Syria also started filling the lake behind its newly constructed Thawra Dam. Simultaneously, the area was hit by a significant drought (Kalpakian, 2004). As a result, the flow of the Euphrates River entering Iraq was reduced to a trickle. Iraq accused Syria of this reduction and of endangering the lives of three million Iraqi farmers dependent on river irrigation water (Morris, 1997). Iraq complained that the flow had dropped from the normal 920 m^3/sec to an unacceptable 197 m^3/sec (Priscoli and Wolf, 2009). Iraq requested an intervention by the Arab League; however, Syria argued that it was receiving less water from Turkey as well and refused to cooperate. As the tension increased, Syria

closed its airspace to all Iraqi aircraft, suspended Syrian flights to Baghdad, and transferred troops from the Israeli border to the Iraqi frontier by May 1975 (Morris, 1997). Iraq also sent its troops to the shared border and threatened to bomb Syria's dam.

Before the conflict could escalate any further, Saudi Arabia and the Soviet Union intervened - only mediation on the part of Saudi Arabia was able to alleviate the situation (Priscoli and Wolf, 2009). On June 3, 1975, an agreement between Iraq and Syria, with the mediation of Saudi Arabia, averted the impending war. The agreement stipulated that Syria is to release extra amounts of water to Iraq (Akanda et al., 2007): specifically, 58% of what Syria receives from the Euphrates is to be released to Iraq (Priscoli and Wolf, 2009). In addition to resolving the conflict, Saudi Arabia contributed to a basin fund that would finance irrigation reform and other methods to reduce unmet demands (Akanda et al., 2007).

4.1.2 The Conflict in 1990

In 1977, Turkey announced plans for the largest water resources project in South-Eastern Anatolia, referred to as "Güneydogu Anadolu Projesi", commonly known as the "GAP Project", which includes 22 dams and 19 hydropower installations on the Euphrates-Tigris (Frenken et al., 2009). The incentive for this project, apart from the steadily increased water demand, was to promote Turkey?s internal stability. Turkey has been continually preoccupied with the rebellion movement of the Kurdish Workers Party (PKK), which is

Figure 4.1: The Euphrates River along with the dams constructed on it (The New York Times, 2009)

struggling to create a Kurdish state in South Eastern Turkey (Güner, 1998). The construction of the GAP project scattered the Kurdish rebels and the PKK denounced the GAP project as harmful to Kurds and their villages. GAP irrigation projects transformed the geography of the area and obstructed the free movement of the PKK. The PKK had targeted the GAP project with sabotage and kidnapping of engineers in order to stop the development. Aside from weakening the PKK movement, the GAP project also provided extra jobs for resident Kurds, thereby promoting internal stability. It also helped in stemming the flow of immigrants from this region to the already over-crowded cities.

On the other hand, both Syria and Iraq demonstrated their distrust and rejection of the GAP project. When Turkey requested funding from the World Bank for a second

dam after the Keban Dam, Syria and Iraq raised many objections to urge the World Bank to withhold the funding, although the Bank and Turkey concluded that the downstream requirements could be satisfied (Akanda et al., 2007). During the conflict between Turkey and PKK, Syria supported the PKK by granting their leader refugee status and provided him with shelter. Moreover, Syria allowed PKK to have military bases in the Beqaa Valley, a region in eastern Lebanon under Syria?s control (Güner, 1998). Syrian support of the PKK was potentially intended for the reduction, or at least the interruption, of the GAP project (Güner, 1998). In 1987, Turkey guaranteed a minimum water flow of 500 m^3/s and Syria, in return, promised to cooperate in security matters. A few months later, Turkey complained about terrorist activities and accused Syria of supporting them (Güner, 1998). Turkey allegedly hinted at a cut in the flow of Euphrates water to Syria over Syrian support for Kurdish terrorists (Starr, 1991). In January 1990, Turkey completely stopped the flow of the Euphrates. The official justification for the interruption was to fill the lake behind the Ataturk Dam and the interruption was intended to be only for one month (Darwish, 1994). Behind the scenes, this interruption was an indirect threat to Syria for its continued support of the PKK. Turkey did not care about Iraq?s reaction as Syria and Iraq were bitter enemies; however, Turkey?s actions united both Iraq and Syria against it. Once Turkey halted the flow of the Euphrates, both countries, Syria and Iraq, boycotted companies involved in the GAP project. Furthermore, military leaders from both nations drew up plans for armed retaliation against Turkey (Darwish, 1994). After three weeks, water was released in the Euphrates River, even though the interruption was intended to last a whole month.

4.1.3 The Conflict in 1998

After the joint coalition between Syria and Iraq in 1990, Turkey decided not to use the Euphrates as a weapon in order to avoid Iraq?s intervention. However, Syria's continuous support for the PKK was affecting Turkey's stability and depleting its resources. Despite bilateral security agreements between Syria and Turkey in 1992 and 1993, Turkey continued to accuse Syria of supporting the PKK, while Syria insisted that it forced the PKK to move its bases from Syrian territory in conformity with the bilateral agreements between itself and Turkey (Güner, 1998). In 1993, the Turkish Prime Minister declared that if Syria did not ban PKK from its country, there could be no solution to the water problem. The issue was raised again in the trilateral summit of 1994 between the Foreign Ministers of Turkey, Syria, and Iraq with no improvements. Moreover, in 1995, Turkey organized military operations in northern Iraq against PKK members who fled to Syria, thus confirming Turkish suspicions. Finally, in 1998, Turkey charged Syria with support of the PKK and harboring its leader, perhaps providing refuge to the leader in Damascus. Turkey escalated the situation and threatened to invade Syria. Egypt intervened and the Egyptian President, Hosni Mubarak, secured Syria's pledge to stop supporting the PKK (Akanda et al., 2007). On account of the intervention of Egypt and in order to avert an invasion by Turkey, the Syrian government agreed to ban PKK from Syria by signing the Adana Agreement on October 20, 1998 (Priscoli and Wolf, 2009). Finally, Table 4.1 provides the historical evolution of the most notable events related to the Euphrates conflicts.

Dates	Events
Early 1970s	Rebellious Kurdish Workers Party (PKK) was formed. Syria supported this party.
Late 1974	The filling of Keban and Thawra dams started.
Early 1975	Iraq complained about the flows in the Euphrates dropping from the normal 920 m^3/sec to an "intolerable" 197 m^3/sec. Iraq requested that the Arab League intervene. However, Syria said it was receiving less than average flow and dropped out of the Arab League. Both countries amassed their troops on the shared borders and the situation escalated.
June 3, 1975	Intervention and mediation efforts by Saudi Arabia are at last successful and war was averted. Agreement details were not announced.
1977	Turkey announced plans for the "GAP Project", which includes 22 dams and 19 hydropower installations on the Euphrates-Tigris Rivers.
1987	Turkey guaranteed a minimum water flow of 500 m^3/s and Syria, in return, promised to cooperate in security matters. A few months later, Turkey complained about terrorist activities and accused Syria of supporting them.
January, 1990	The filling of the Ataturk Dam by Turkey started, shutting off completely the flow to the Euphrates River. Even though the interruption was intended to be for only one month, Syria and Iraq boycotted companies involved in the GAP project. Moreover, military leaders from both nations drew up plans for armed retaliation against Turkey. After three weeks, Turkey released water to the Euphrates River.
1992 – 1994	Bilateral security agreements between Syria and Turkey were discussed, with little success. Turkey continued to accuse Syria of supporting the PKK. In 1993, the Turkish Prime Minister declared that if Syria did not ban PKK from its country, there could be no solution to the water problem.
1995	Turkey organized military operations in northern Iraq against PKK members who fled to Syria, thus confirming Turkish suspicions.
August, 1998	Turkey threatened full military action and invasion against Syria for continuing to support PKK rebels.
October, 1998	With the mediation of Egypt, the Adana Agreement, obligating the Syrian government to ban PKK, was signed by Turkey and Syria.

Table 4.1: Notable events related to conflicts along the Euphrates River

4.2 Conflict Analysis of the 1975 Dispute

The DMs and options for the 1975 conflict are given in Table 4.2. Notice that Syria has an option regarding the release of the water plus an option of escalating the situation. Iraq has the single option of attacking Syria. Since both Saudi Arabia and the Soviet Union have similar preferences and reasons for getting involved, they are considered as a single DM labeled as "Third Party". The Third Party has a single option of acting or not. Table 4.2 describes the options for each DM. Each option is labeled with a number and can be either taken (Y for yes) or not (N for no). For example, option 3, which is entitled Attack, is the situation in which Iraq can use military action to force Syria to release water into the Euphrates. Undertaking this option, as indicated by Y for yes, means using force, while not taking this option, N for no, indicates accepting the situation and allowing Syria to fill the Thawra Dam without escalation.

DM	Option	Choice	Description
Syria	1.Release Water	**Y**	Syria agrees to halt the filling of Thawra Dam and let the Euphrates flow into Iraq
		N	Syria continues to fill its dam
	2.Escalate	**Y**	This could be done by cutting relations with Iraq, sending troops to the shared border, closing the air space to Iraqi aircraft, or any combination of these actions
		N	Syria does not undertake any of the escalating options
Iraq	3.Attack	**Y**	This includes bombing of the dam and going to war with Syria
		N	Iraq does not act and accepts the situation
Third Party	4.Act	**Y**	This includes mediation and reconciliation between the two countries and monetary support
		N	Do not intervene

Table 4.2: DMs, options and descriptions for the 1975 conflict

To emphasize the effect of the third party, this conflict will be analyzed without and

with the intervention of the third party. The sets of possible states are given in Tables 4.3 and 4.4, respectively. Notice that there is one infeasible situation in which Syria both releases the water and escalates the situation at the same time (mutually exclusive options). Taking this into account resulted in the removal of two states in the model without the intervention of the third party and the removal of four states in the model with the participation of the third party.

DM	**Option**	**States**					
Syria	1.Release Water	**N**	**Y**	**N**	**N**	**Y**	**N**
	2.Escalate	**N**	**N**	**Y**	**N**	**N**	**Y**
Iraq	3.Attack	**N**	**N**	**N**	**Y**	**Y**	**Y**
Label		1	2	3	4	5	6

Table 4.3: DMs, options and states for the 1975 conflict without the third party

DM	**Option**	**States**											
Syria	1.Release Water	N	Y	N	N	Y	N	N	Y	N	N	Y	N
	2.Escalate	N	N	Y	N	N	Y	N	N	Y	N	N	Y
Iraq	3.Attack	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y
Third Party	4.Act	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
Label		1	2	3	4	5	6	7	8	9	10	11	12

Table 4.4: DMs, options and states for the 1975 conflict with the third party

Figures 4.2 and 4.3 show the integrated Graph Model of the conflict both without and with the participation of the third party, respectively. The numbers in the nodes refer to the state numbers as indicated in Tables 4.3 and 4.4. The lines with arrows between the nodes are moves that can be carried out by the indicated DM in one step.

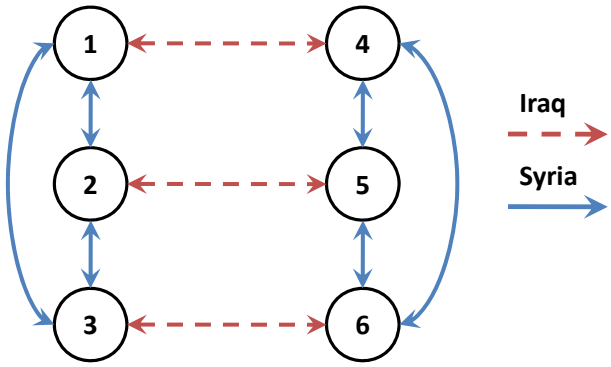

Figure 4.2: Integrated Graph Model of the 1975 conflict without the third party

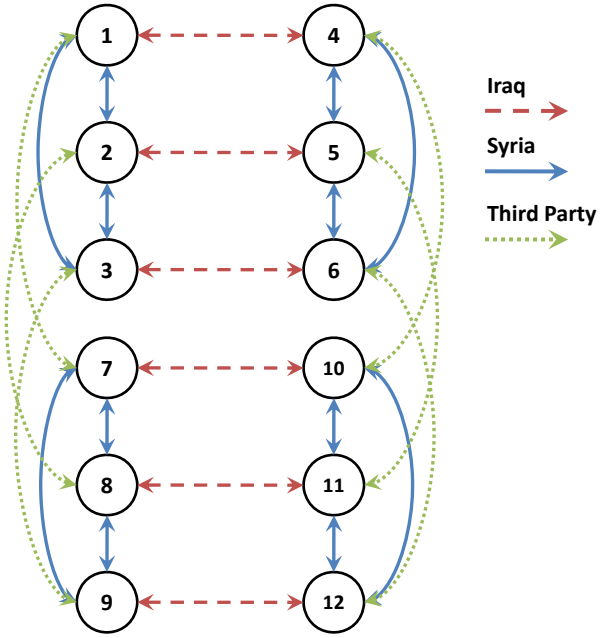

Figure 4.3: Integrated Graph Model of the 1975 conflict with the third party

Table 4.5 presents the preference prioritization information for each DM in the 1975 conflict without the participation of the third party, from most important at the top to least important at the bottom for each DM. The statements presented herein are a sample of how the ranking of states is constructed. This information is used to order the states from most to least preferred by the DM. Assuming transitivity for the preferences, Table 4.6 presents the ranking of states from most to least preferred for both Syria and Iraq using option prioritization (Hipel et al., 1997; Fang et al., 2003a,b). For example, State 1, which is the status quo, is the best state to be in for Syria. State 5, in which Syria releases the Euphrates and Iraq attacks at the same time, is considered the worst possible state for Syria.

DM	P#	Preference Information (From most to least important)	Further Explanation
Syria	**1**	Remain at the status quo	Syria continues filling its dam and Iraq accepts the situation without any escalation or intervention
	2	Escalate the situation if Iraq decides to attack	Syria next prefers going to war with Iraq if it is attacked, which is more preferred than releasing water
Iraq	**1**	Syria releases more flow of the Euphrates River	Iraq most prefers the situation in which Syria stops filling its dam without any escalation
	2	Execute an attack if Syria does not release more water	Iraq's interest in water far outweighs the consequence of going to war

Table 4.5: Preference prioritization information for the 1975 conflict without the third party

DM	States					
Syria	**1**	**3**	**6**	**2**	**4**	**5**
Iraq	**2**	**4**	**6**	**1**	**5**	**3**
	Most Preferred				*Least Preferred*	

Table 4.6: Ranking of states for the DMs in the 1975 conflict without the third party

The third party could be viewed as an actual DM if it has its own options and preferences. However, if the party is not an actual stakeholder in the conflict but is motivated to bring about a more preferred equilibrium, then it can be categorized as Arbitrator, Coordinator or Donor (Sakamoto et al., 2005). If the party has the influence to change other DMs' preferences or options, then the party is called a Donor. On the other hand, if the party has the power to exclude some states, then it is considered to be an Arbitrator. In this conflict, the third party, Saudi Arabia, is clearly a Donor as it contributed to financing the basin development and both DMs, Syria and Iraq, want to please Saudi Arabia. Therefore, DMs' preferences, especially on the part of Syria, are changed. Table 4.7 presents the preference prioritization information for each DM in the 1975 conflict with the participation of the third party from most to least preferred. Table 4.8 gives the preferences for Syria, Iraq, and the third party from most to least preferred.

DM	P#	Preference Information (From most to least important)	Explanation
Syria	**1**	Remain at the status quo	Syria continues filling its dam and Iraq accepts the situation without any escalation or intervention
	2	Release the flow of the Euphrates if and only if Iraq does not attack and with the mediation of a third party	This is the new preference information after the intervention of the Third Party
	3	Escalate the situation if Iraq decides to attack	Syria's least preferred situation is to go to war with Iraq
Iraq	**1**	Syria releases the flow of the Euphrates	Iraq's most preferred situation is that Syria stops the filling of its dam without any escalation and with or without an intervention
	2	Strike an attack if Syria does not release more water	Iraq's interest in water far outweighs the consequence of going to war
Third Party	**1**	Acts and influences Syria to release the flow of the Euphrates	The mediator's interest is to promote peace in the region and reduce harm for everyone

Table 4.7: Preference prioritization information for the 1975 conflict with the third party

DM	States											
Syria	1	3	8	9	2	7	12	6	10	4	11	5
Iraq	8	2	6	12	4	10	7	5	11	1	9	3
Third Party	8	2	1	7	9	3	4	10	6	12	5	11
	Most Preferred											*Least Preferred*

Table 4.8: Ranking of states for the DMs in the 1975 conflict with the third party

The objective of the analysis is to determine the equilibrium states, which are the states from which no DM is motivated to move and, therefore, the conflict will probably end at that particular state. To determine the equilibrium states we use stability definitions (or solution concepts), which describe human behavior and patterns based on moves

and counter moves. Equilibria are states that are stable for all DMs. After inputting the foregoing information into the decision support system GMCR II, equilibrium results are obtained for both Syria and Iraq without the third party (Table 4.9) and with the third party (Table 4.10). Restricting Iraq's alternative of attacking does not affect the equilibria for both cases. In Tables 4.9 and 4.10, the left column gives the different stability definitions while the remaining columns present the stability calculation results for each solution concept corresponding to the state. Nash and Sequential Stability (SEQ) are considered the strongest stability definitions. General Metarationality (GMR) and Symmetric Metarationality (SMR) are not considered as strong stability definitions since DMs are permitted to harm themselves during the process of sanctioning. Fang et al. (1989) discuss the relationships among the different solution concepts.

Solution Concepts	**States**	**1**	**2**	**3**	**4**	**5**	**6**
R (Nash)							✓
GMR		✓					✓
SMR		✓					✓
SEQ							✓

Table 4.9: Equilibrium results for the 1975 conflict without the third party

Solution Concepts	**States**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
R (Nash)							✓		✓				
GMR			✓				✓	✓	✓				✓
SMR			✓				✓	✓	✓				✓
SEQ							✓		✓				

Table 4.10: Equilibrium results for the 1975 conflict with the third party

It is clear from the aforementioned analysis that when the third party does not participate (Table 4.9), the strongest equilibrium is state 6 which means that both Syria and Iraq

go to war. And that is what nearly happened as both countries amassed their troops on their shared border. The status quo, State 1, is a very weak equilibrium and the unilateral improvement by Iraq will most likely be taken; that is, Iraq will move to state 4 in which it will attack. In contrast, with the intervention of the third party, a new equilibrium is introduced: State 8 in which Syria releases water and no escalation or attack from Iraq occurs. Referring to the ranking of states in Tables 4.6 and 4.8 as well as the integrated graphs in Figures 4.2 and 4.3, one can easily view the unilateral moves and improvements for each DM. A unilateral move is any possible move controlled by that particular DM, whereas a unilateral improvement necessitates that this move is also a movement to a more preferred state. The analysis of the conflict demonstrates how each DM's preferences may have an impact on the overall conflict. Table 4.11 provides the actual historical evolution of the conflict when moving from the status quo on the left via several intermediate states to the final equilibrium on the right. One can clearly see how both Syria and Iraq almost went to war until the third party intervened. It is clear that the actual historical evolution of the conflict is consistent with the earlier analysis.

DM	**Option**	**Status Quo**		Intermediary states		**Equilibrium**
Syria	Release Water	N	N	N	N	→ Y
	Escalate	N	N →	Y	Y	→ N
Iraq	Attack	N →	Y	Y	Y	→ N
Third Party	Act	N	N	N →	Y	Y
Label		1	4	6	12	8

Table 4.11: Historical evolution of the 1975 conflict

4.3 Strategic Study of the 1990 Conflict

4.3.1 Modeling and analysis

The DMs and options for the 1990 conflict are given in Table 4.12. Turkey has two options: escalate the dispute with Syria and/or decrease the flow of the Euphrates. Syria possesses the two options of stopping its support for the PKK or escalating the situation. Iraq controls the single option of escalating the situation against Turkey.

DM	Option	Choice	Description
Turkey (T)	Escalate	**Y**	This includes an attack on Syria, massing the troops on the shared border with Syria
		N	Do not escalate
	Euphrates Cutoff/ Reduction	**Y**	This includes stopping or reducing the flow of the Euphrates to Syria and further to Iraq
		N	Turkey will allow the river to flow
Syria (S)	Stop PKK Support	**Y**	This includes banning of the PKK in Syria and the extradition of PKK leader to Turkey
		N	Syria continues to support PKK rebels
	Escalate	**Y**	This includes attacks on Turkey and its development projects
		N	Not escalating the situation
Iraq (I)	Escalate	**Y**	Iraq will join Syria against Turkey
		N	Iraq will accept the situation and do nothing

Table 4.12: DMs, options and description for the 1990 conflict

The set of possible feasible states is given in Table 4.13. Notice that the number of mathematically possible states equals $2^5 = 32$ since there are 5 options each of which can be taken or not. However, Syria cannot both ban PKK and escalate at the same time (mutually exclusive options) and there is no point for Iraq to escalate if Turkey does not

cut the water and Syria does not escalate. Removing the foregoing infeasible situations leads to a total of 20 feasible states or scenarios.

DM	Option																				
T	Escalate	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
	Cut Euphrates	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y
S	Ban PKK	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	N	N	N	N
	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
I	Escalate	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Label		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**

Table 4.13: DMs, options and states for the 1990 conflict

This conflict is now analyzed using a regular analysis and an in-depth coalition analysis based on the procedure described by Kilgour et al. (2001) and Inohara and Hipel (2008b,a). Figure 4.4 illustrates the possible moves by Turkey. Figure 4.5 shows the Integrated Graph Model of the conflict and possible moves by each of Syria and Iraq unilaterally. Figure 4.6 displays the Coalition Graph Model of the conflict for both DMs, Syria and Iraq. Coalition improvements are denoted in this graph by a filled-in circle while coalition moves are denoted by a normal arrow. For example, from state 18 (top right corner) in Figure 4.6, there is a coalition move to states 2 and 10. However, the coalition move to state 10 is a coalition improvement by both Syria and Iraq.

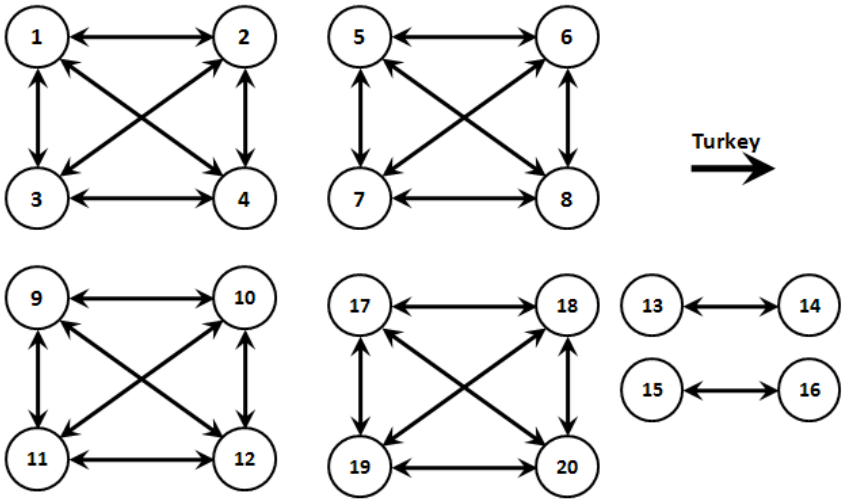

Figure 4.4: Graph Model of the 1990 conflict for movements by Turkey

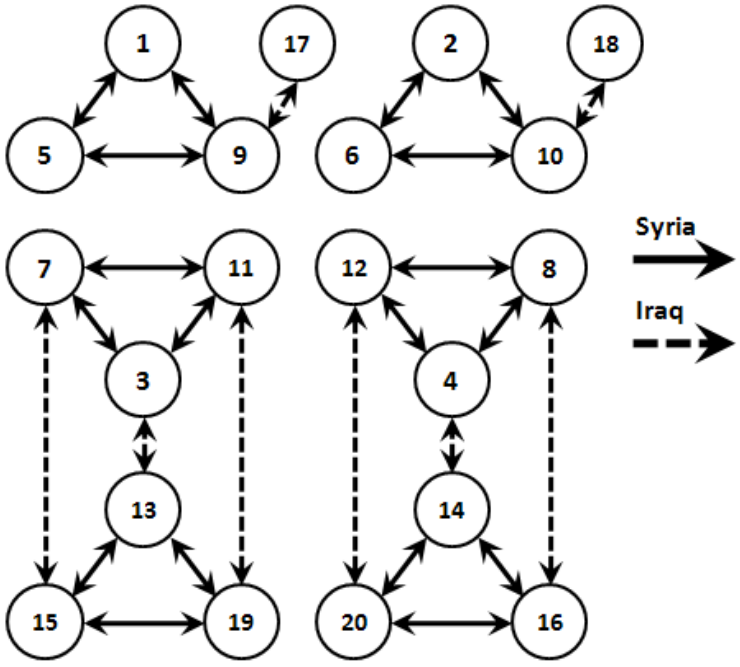

Figure 4.5: Integrated Graph Model of the 1990 conflict for both Syria and Iraq

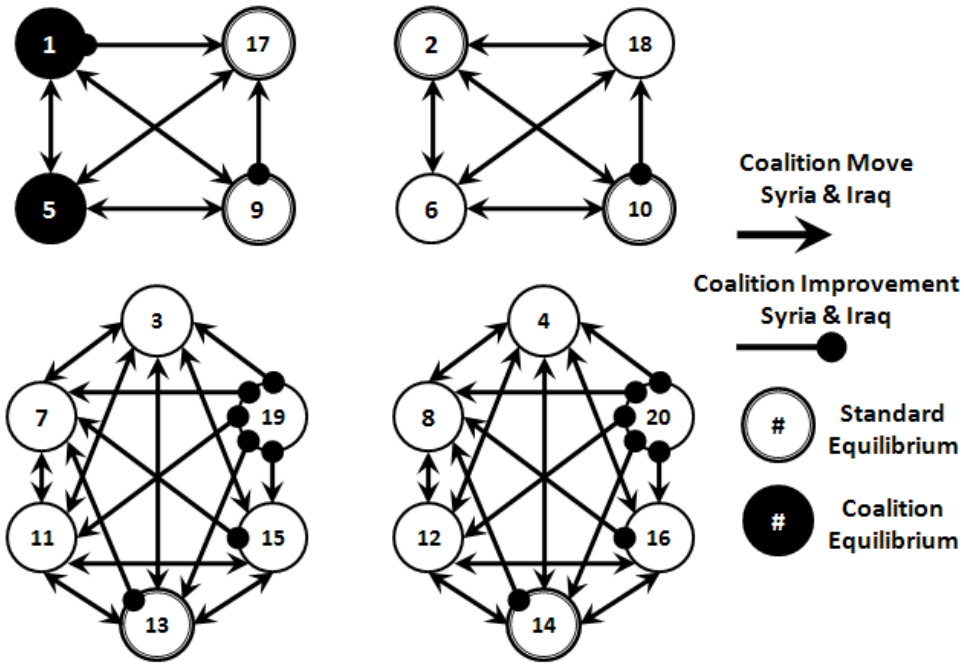

Figure 4.6: Coalition Graph Model of the 1990 conflict for a coalition of Syria and Iraq

Table 4.14 presents the preference prioritization information for each DM of the 1990 conflict without the participation of the Third Party from most to least important. Table 4.15 presents the ranking of states for all DMs in the conflict from most to least preferred. Equally preferred states are denoted by a bar above them. Table 4.16 displays the equilibria results for each of the states after inputting the foregoing information into GMCR II.

DM	P#	Preference Information (From most to least important)	Explanation
T	**1**	Syria stops its support for PKK, and reduce the flow of the Euphrates to continue its development projects	
	2	Release the flow of the Euphrates if and only if Syria stops its support for PKK	Turkey does not want to escalate the situation with Syria if the latter banned the PKK
	3	Stop the flow of the Euphrates and escalate the situation against Syria if the latter continues to support PKK and harbor its leader	Turkey's least preferred situation is to go to war. The even worse situation is if both Syria and Iraq escalate at the same time
S	**1**	Syria continues to support the PKK and Turkey allows the Euphrates to flow	
	2	Both Syria and Iraq escalate if Turkey stops the flow or attacks	
	3	Stop supporting PKK if and only if Turkey allows the Euphrates to flow and Iraq does not join in escalating	
I	**1**	Turkey allows the Euphrates to flow	
	2	Escalate if Turkey stops the flow	

Table 4.14: Preference prioritization information for 1990 conflict

DM	States																			
T	7	8	5	6	3	4	1	2	11	12	15	9	10	16	13	14	17	19	20	18
S	1	9	17	5	19	20	10	18	2	3	11	13	4	14	12	6	15	16	8	7
I	1	2	6	5	10	9	19	20	15	16	14	13	18	17	4	7	8	11	12	3
	Most Preferred																		*Least Preferred*	

Table 4.15: Preference vector for DMs in the 1990 conflict

Solution Concepts	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
R (Nash)																				
GMR	✓	✓			✓				✓	✓			✓	✓			✓			
SMR	✓	✓			✓				✓	✓										
SEQ	✓				✓				✓				✓	✓			✓			

Table 4.16: Equilibria results for the 1990 conflict

4.3.2 In-depth coalition analysis

In this subsection, a detailed coalition analysis is undertaken. The procedure for carrying out this analysis was adapted from Kilgour et al. (2001) and Inohara and Hipel (2008b,a). The main steps of the procedure are now outlined briefly, while the detailed procedure can be found in the referenced articles. The first step is to construct the reachable lists $R_H(s)$ of all possible coalitions. This is illustrated in Table 4.17. For simplicity and to save space, Turkey, Syria and Iraq are abbreviated as T, S, and I, respectively. Similarly, the coalition between Turkey and Syria is abbreviated as TS, and so on. Next, one constructs the coalition improvement lists, denoted by $R_H^{(++)}(s)$, of possible coalitions. Table 4.18 provides the results of this step.

s/h	T	S	I	TS	TI	SI	TSI
1	{2,3,4}	{5,9}	∅	{2,3,4,5,6,7,8,9,10,11,12}	{2,3,4,13,14}	{5,9,17}	{2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20}
2	{1,3,4}	{6,10}	∅	{1,3,4,5,6,7,8,9,10,11,12}	{1,3,4,13,14}	{6,10,18}	{1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20}
3	{1,2,4}	{7,11}	{13}	{1,2,4,5,6,7,8,9,10,11,12}	{1,2,4,13,14}	{7,11,13,15,19}	{1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20}
4	{1,2,3}	{8,12}	{14}	{1,2,3,5,6,7,8,9,10,11,12}	{1,2,3,13,14}	{8,12,14,16,20}	{1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20}
5	{6,7,8}	{1,9}	∅	{1,2,3,4,6,7,8,9,10,11,12}	{6,7,8,15,16}	{1,9,17}	{1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20}
6	{5,7,8}	{2,10}	∅	{1,2,3,4,5,7,8,9,10,11,12}	{5,7,8,15,16}	{2,10,18}	{1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20}
7	{5,6,8}	{3,11}	{15}	{1,2,3,4,5,6,8,9,10,11,12}	{5,6,8,15,16}	{3,11,13,15,19}	{1,2,3,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20}
8	{5,6,7}	{4,12}	{16}	{1,2,3,4,5,6,7,9,10,11,12}	{5,6,7,15,16}	{4,12,14,16,20}	{1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20}
9	{10,11,12}	{1,5}	{17}	{1,2,3,4,5,6,7,8,10,11,12}	{10,11,12,17,18,19,20}	{1,5,17}	{1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20}
10	{9,11,12}	{2,6}	{18}	{1,2,3,4,5,6,7,8,9,11,12}	{9,11,12,17,18,19,20}	{2,6,18}	{1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20}
11	{9,10,12}	{3,7}	{19}	{1,2,3,4,5,6,7,8,9,10,12}	{9,10,12,17,18,19,20}	{3,7,13,15,19}	{1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,19,20}
12	{9,10,11}	{4,8}	{20}	{1,2,3,4,5,6,7,8,9,10,11}	{9,10,11,17,18,19,20}	{4,8,14,16,20}	{1,2,3,4,5,6,7,8,9,10,11,12,14,15,16,17,18,19,20}
13	{14}	{15,19}	{3}	{14,15,16,17,18,19,20}	{1,2,3,4,14}	{3,7,11,15,19}	{1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20}
14	{13}	{16,20}	{4}	{13,15,16,17,18,19,20}	{1,2,3,4,13}	{4,8,12,16,20}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20}
15	{16}	{13,19}	{7}	{13,14,16,17,18,19,20}	{5,6,7,8,16}	{3,7,11,13,19}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20}
16	{15}	{14,20}	{8}	{13,14,15,17,18,19,20}	{5,6,7,8,15}	{4,8,12,14,20}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20}
17	{18,19,20}	∅	{9}	{13,14,15,16,18,19,20}	{9,10,11,12,18,19,20}	{1,5,9}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,19,20}
18	{17,19,20}	∅	{10}	{13,14,15,16,17,19,20}	{9,10,11,12,17,19,20}	{2,6,10}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,19,20}
19	{17,18,20}	{13,15}	{11}	{13,14,15,16,17,18,20}	{9,10,11,12,17,18,20}	{3,7,11,13,15}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20}
20	{17,18,19}	{14,16}	{12}	{13,14,15,16,17,18,19}	{9,10,11,12,17,18,19}	{4,8,12,14,16}	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19}

Table 4.17: Reachable lists $R_H(s)$ for the 1990 conflict

s/H	T	S	I	TS	TI	SI	TSI
1	{3,4}	Ø	Ø	Ø	Ø	Ø	Ø
2	{1,3,4}	{10}	Ø	{1,5}	Ø	Ø	Ø
3	Ø	Ø	{13}	{5}	Ø	{19}	{5}
4	{3}	Ø	{14}	{3,5}	Ø	{20}	{5}
5	{7,8}	{1,9}	Ø	Ø	Ø	Ø	Ø
6	{5,7,8}	{2,10}	Ø	{5}	Ø	Ø	Ø
7	Ø	{3,11}	{15}	Ø	Ø	{13,15,19}	Ø
8	{7}	{4,12}	{16}	Ø	Ø	{14,16,20}	Ø
9	{11,12}	{1}	Ø	{1}	Ø	Ø	Ø
10	{9,11,12}	Ø	Ø	{1,5,9}	Ø	Ø	Ø
11	Ø	{3}	{19}	{1,2,3,5}	Ø	{19}	{1,2,5}
12	11	Ø	{20}	{1,2,3,5}	Ø	{20}	{1,2,5}
13	Ø	{19}	Ø	Ø	{1,2}	{19}	{1,2,5,9,10}
14	{13}	{20}	Ø	Ø	{1,2}	{20}	{1,2,5,1,0}
15	Ø	{13,19}	Ø	Ø	{6}	{19}	{1,2,5,6}
16	{15}	{14,20}	Ø	{15}	{5,6}	{20}	{1,2,5,6,9,10}
17	Ø	Ø	{9}	Ø	{9,10}	{1,9}	{1,9}
18	{17,19,20}	Ø	{10}	{17,19,20}	{9,10,19 20}	{10}	{159,10,1920}
19	{17}	Ø	Ø	{17}	{9,10}	Ø	{1,5,9}
20	{17,19}	Ø	Ø	{17,19}	{9,10,19}	Ø	{15,919}

Table 4.18: Coalition improvement lists $R_H^{(++)}(s)$ for the 1990 conflict

The third step is to construct the stability tableau. Table 4.19 illustrates the construction of the table. The fourth step is to calculate the stability of each state for each DM according to the solution concepts with respect to the various coalitions. Notice that improvements written alone without squiggly parentheses (i.e.{ }) indicate unilateral improvements by that DM. Improvements written to the left of squiggly parentheses mean that these improvements are carried out with the coalition given within the squiggly parentheses. For example, from state 9, Turkey has a unilateral improvement to states 11 and 12. Turkey also has a coalition improvement from state 9 to 1 if it formed a coalition with Syria in this case and so on.

Finally, to determine the coalition equilibrium according to a specific solution concept, the state under consideration should be stable for all of the DMs. In Table 4.19 the conflict is examined according to both CNash (i.e. Coalition Nash Stability) and CSEQ (i.e. Coalition Sequential Stability). The coalition stability is a generalization of the individual stability. Other solution concepts can be assessed as well. However, as this conflict is fairly large and contains 20 states, the analysis is limited to these two solution concepts.

Overall Coalition Stability	**x**	**x**	**E**	**x**	**x**	**x**	**E**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
DM Stability	**r**	**s**	**s**	**s**	**u**	**u**	**s**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**	**u**
Turkey	**7**	**8**	**5**	**6**	**3**	**4**	**1**	**2**	**11**	**12**	**15**	**9**	**10**	**16**	**13**	**14**	**17**	**19**	**20**	**18**
		7	7 8	5 7 8	5{TS}	3 3{TS} 5{TS}	3 4	1 3 4 1{TS} 5{TS}	1{TS} 2{TS} 3{TS} 5{TS} 1{TSI} 2{TSI} 5{TSI}	11 1{TS} 2{TS} 3{TS} 5{TS} 1{TSI} 2{TSI} 5{TSI}	6{TI} 1{TSI} 2{TSI} 5{TSI} 6{TSI}	11 12 1{TS}	9 11 12 1{TS} 5{TS} 9{TS}	15 15{TS} 1{TSI} 2{TSI} 5{TSI} 6{TSI} 9{TSI} 10{TSI}	1{TI} 2{TI} 1{TSI} 2{TSI} 5{TSI} 9{TSI} 10{TSI}	13 1{TI} 2{TI} 1{TSI} 2{TSI} 5{TSI} 10{TSI}	9{TI} 10{TI} 1{TSI} 9{TSI}	17 17{TS} 9{TI} 10{TI} 1{TSI} 9{TSI}	17 19 17{TS} 19{TS} 9{TI} 10{TI} 19{TI} 1{TSI} 5{TSI} 9{TSI} 19{TSI}	17 19 20 17{TS} 19{TS} 20{TS} 9{TI} 10{TI} 19{TI} 20{TI} 1{TSI} 5{TSI} 9{TSI} 10{TSI} 19{TSI} 20{TSI}
DM Stability	r	u	u	s	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
Syria	**1**	**9**	**17**	**5**	**19**	**20**	**10**	**18**	**2**	**3**	**11**	**13**	**4**	**14**	**12**	**6**	**15**	**16**	**8**	**7**
		1 1{TS}	1{SI} 9{SI} 1{TSI} 9{TSI}	1 9	17{TS} 1{TSI} 5{TSI} 9{TSI}	17{TS} 19{TS} 1{TSI} 5{TSI} 9{TSI} 19{TSI}	1{TS} 5{TS} 9{TS}	17{TS} 19{TS} 20{TS} 10{SI} 1{TSI} 5{TSI} 9{TSI} 10{TSI} 19{TSI} 20{TSI}	10 1{TS} 5{TS}	5{TS} 19{SI} 5{TSI}	3 1{TS} 2{TS} 3{TS} 5{TS} 19{SI} 1{TSI} 2{TSI} 5{TSI}	19 19{SI} 1{TSI} 2{TSI} 5{TSI} 9{TSI} 10{TSI}	3{TS} 5{TS} 20{SI} 5{TSI}	20 20{SI} 1{TSI} 2{TSI} 5{TSI} 10{TSI}	1{TS} 2{TS} 3{TS} 5{TS} 20{SI} 1{TSI} 2{TSI} 5{TSI}	2 10 5{TS}	13 19 19{SI} 1{TSI} 2{TSI} 5{TSI} 6{TSI}	14 20 15{TS} 20{SI} 1{TSI} 2{TSI} 5{TSI} 6{TSI} 9{TSI} 10{TSI}	4 12 14{SI} 16{SI} 20{SI}	3 11 13{SI} 15{SI} 19{SI}
DM Stability	r	r	r	r	r	r	u	u	u	u	u	u	u	u	u	u	u	u	u	u
Iraq	**1**	**2**	**6**	**5**	**10**	**9**	**19**	**20**	**15**	**16**	**14**	**13**	**18**	**17**	**4**	**7**	**8**	**11**	**12**	**3**
							9{TI} 10{TI} 1{TSI} 5{TSI} 9{TSI}	9{TI} 10{TI} 19{TI} 1{TSI} 5{TSI} 9{TSI} 19{TSI}	6{TI} 19{SI} 1{TSI} 2{TSI} 5{TSI} 6{TSI}	5{TI} 6{TI} 20{SI} 1{TSI} 2{TSI} 5{TSI} 6{TSI} 9{TSI} 10{TSI}	1{TI} 2{TI} 20{SI} 1{TSI} 2{TSI} 5{TSI} 10{TSI}	1{TI} 2{TI} 19{SI} 1{TSI} 2{TSI} 5{TSI} 9{TSI} 10{TSI}	10 9{TI} 10{TI} 19{TI} 20{TI} 10{SI} 1{TSI} 5{TSI} 9{TSI} 10{TSI} 19{TSI} 20{TSI}	9 9{TI} 10{TI} 1{SI} 9{SI} 1{TSI} 9{TSI}	14 20{SI} 5{TSI}	15 13{SI} 15{SI} 19{SI}	16 14{SI} 16{SI} 20{SI}	19 19{SI} 1{TSI} 2{TSI} 5{TSI}	20 20{SI} 1{TSI} 2{TSI} 5{TSI}	13 19{SI} 5{TSI}

Table 4.19: Stability analysis tableau for coalition sequential stability for the 1990 conflict

4.3.3 Insights on the 1990 conflict

Although no rational (Nash) coalition stability is present in this conflict, states 1 and 5 are sequentially stable by coalition sanctioning and, therefore, one can confidently state that

the conflict will end up at one of these two states. Historically, the conflict concluded at state 1, as will be described in the evolution of the conflict.

The construction of the different types of Graph Models in Figures 4, 5, and 6 give a very clear understanding of the conflict and how it can evolve by unilateral moves by each DM as well as by a coalition. This forms a framework to communicate the conflict to stakeholders. Moreover, different moves and counter-moves can be easily assessed and compared especially in a complicated conflict like this one. From the analysis given in Table 4.16, one can see that there is no rational Nash stable state. However, three states have fairly strong equilibria by sequential sanctioning and symmetric metarationality: states 1, 5, and 9. These states represent the status quo, banning PKK, and escalating the situation unilaterally by Syria. An examination of these results eliminates the possibility of forming a coalition, which happened historically, and none of these equilibria includes escalation by Iraq.

After performing the in-depth coalition analysis, no new equilibrium jump is introduced but coalition moves can be spotted and taken into account. The lesson learned from this conflict is that one should account for coalition moves and improvements. The historical evolution of the conflict (4.20) shows how Turkey?s action formed a coalition between the bitter enemies, Syria and Iraq, forcing Turkey to revert to the status quo equilibrium. Furthermore, in complicated conflicts like this one, one must be very careful to choose the right preference information as the conflict resolutions can be highly sensitive to preferences. This is especially true when many political factors are considered.

DM	Option	Status Quo	The conflict lasted only 3 weeks			Final Equilibrium
T	Escalate	**N**	**N**	**N**	**N**	**N**
	Reduce Euphrates	**N** →	**Y**	**Y** →	**N**	**N**
S	Ban PKK	**N**	**N**	**N**	**N**	**N**
	Escalate	**N**	**N** →	**Y**	**Y** →	**N**
I	Escalate	**N**	**N** →	**Y**	**Y** →	**N**
Label		**1**	**3**	**19**	**17**	**1**

Table 4.20: Historical evolution of the 1990 conflict

4.4 Strategic Investigation of the 1998 Controversy

The DMs and options for the 1998 conflict are given in Table 4.21. Turkey has two options: escalate the situation against Syria or carry out a full invasion. Syria has two options of stopping its support for the PKK or escalating the situation. The third party, Egypt, has a single option of acting or not.

DM	Option	Choice	Description
Turkey	Escalate	**Y**	This includes threatening Syria, and massing the troops on the shared border with Syria
		N	Do not escalate
	Invade	**Y**	This includes an invasion of Syria and the declaration of war
		N	Do not attack
Syria	Stop PKK Support	**Y**	This includes banning of the PKK in Syria and the extradition of PKK leader to Turkey
		N	Syria continues to support PKK rebels
	Escalate	**Y**	This includes attacks on Turkey and its development projects
		N	Do not escalate
Third Party	Act	**Y**	This includes mediation and reconciliation between the two countries of Turkey and Syria.
		N	Do not intervene

Table 4.21: DMs, options and descriptions for the 1998 conflict

The set of feasible states is provided in Table 4.22. Note that there is one infeasible situation in which Syria can both ban PKK and escalate at the same time (mutually exclusive options). Also notice that state 9 is an indistinguishable state if Turkey decides to invade Syria, since a full scale war will occur and the game will end. Because the third party played an Arbitrator role in this conflict, the situation in which it acts and Syria does not ban the PKK, is removed. The remaining possible states or scenarios are provided in Table 4.22. Figure 4.7 shows the Integrated Graph Model of the conflict.

DM	**Option**	**States**								
Turkey	Escalate	N	Y	N	Y	N	Y	N	Y	--
	Invasion	N	N	N	N	N	N	N	N	**Y**
Syria	Ban PKK	N	N	Y	Y	N	N	Y	Y	--
	Escalate	N	N	N	N	Y	Y	N	N	--
Third Party	Act	N	N	N	N	N	N	Y	Y	--
Label		1	2	3	4	5	6	7	8	9

Table 4.22: DMs, options and states for the 1998 conflict with the third party

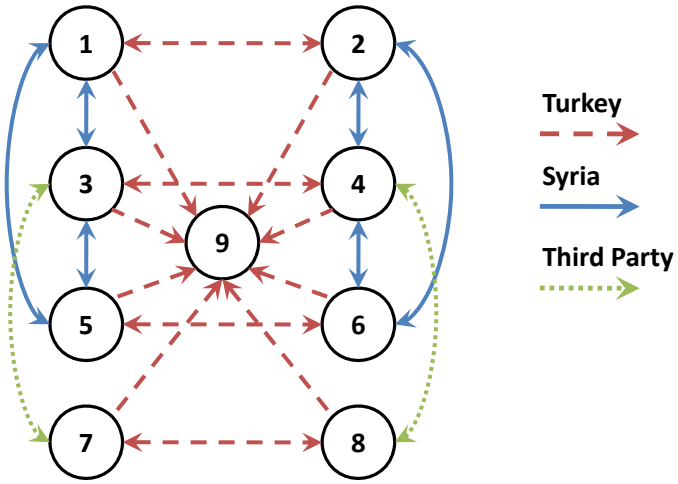

Figure 4.7: Integrated Graph Model of the 1998 conflict with the third party

In this situation, the third party acts as an Arbitrator, since the party has the power to exclude some states (Sakamoto et al., 2005). In this conflict, the third party, Egypt, restricted Syria's move of not banning the PKK if it intervened. Egypt brings to the table legitimacy and extensive experience gained through experience with the conflicts along the Nile basin (Akanda et al., 2007). Syria was united with Egypt under the United Arab Republic (UAR) before Syria declared independence from the UAR in the 1970s. UAR was mostly led by the Egyptian President, Gamal Abdel Nasser. These factors combined to give Egypt a say in Syria's politics. Table 4.23 presents the preference prioritization information for each DM in the 1998 conflict from most to least preferred. Table 4.24 presents the hierarchical preference statements for Turkey, Syria, and the third party from most to least important. Table 4.25 outlines the analysis results after inputting the foregoing information into GMCR II.

DM	P#	Preference Information (From most to least preferred)	Further Explanation or Comments
Turkey	**1**	Syria stops its support for PKK	
	2	Escalate the situation if Syria does not ban PKK	
	3	Invade Syria if and only if Syria does not ban PKK	Turkey's least preferred situation is remaining at the status quo
Syria	**1**	Remain at the status quo	Syria continues to support the PKK and Turkey does not escalate (However, this move is restricted by the Third Party's intervention)
	2	Turkey does not invade	Syria's least preferred situation is an invasion by Turkey
	3	Escalate if Turkey escalates	
Third Party	**1**	Syria stops its support of PKK and Turkey does not invade Syria	Third Party is against the support of the rebellious PKK and wants to bring peace to the area

Table 4.23: Preference prioritization information for the 1998 conflict with the third party

DM	States								
Turkey	3	7	8	4	6	9	2	1	5
Syria	1	5	7	6	2	3	8	4	9
Third Party	7	3	8	4	1	2	5	6	9
	Most Preferred							*Least Preferred*	

Table 4.24: Ranking of states for DMs in the 1998 conflict with the third party

Solution Concepts	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R (Nash)						✓	✓		✓
GMR			✓	✓		✓	✓	✓	✓
SMR			✓	✓		✓	✓	✓	✓
SEQ						✓	✓		✓

Table 4.25: Equilibrium results for the 1998 conflict with the third party

This conflict study shows that Turkey played a more important role than Syria and did not have to use water as a weapon. Moreover, Turkey's superior military power puts it at an advantage, which allowed it to threaten Syria with an invasion, thereby bringing the game to an end. The strongest equilibrium states are 6 and 9 (Table 4.25) in which both Syria and Turkey escalate the situation and Turkey invades eventually if the third party does not act. However, with the mediation of the third party, a new equilibrium came about: state 7 in which the third party acts and Syria bans the PKK. As will be explained in the final section, Syria has been put in a Pareto-inferior situation as it had to give up other things in addition to banning the PKK. The notion of classifying the role of the third party into Arbitrator, Coordinator, and Donor can determine, in advance, how a third party can influence and bring about a potential resolution to the conflict. Table 4.26 shows the actual historical evolution of the 1998 conflict.

DM	Option	Status Quo		Final Equilibrium	
Turkey	Escalate	N	Y	Y	N
	Invasion	N	N	N	N
Syria	Ban PKK	N	N	N	Y
	Escalate	N	N	Y	N
Third Party	Act	N	N	N	Y
Label		1	2	6	7

Table 4.26: Historical evolution of the 1998 conflict

4.5 Fundamental Insights

The analyses confirm similar conclusions drawn by Priscoli and Wolf (2009) in their studies of Middle East water conflicts. Firstly, unilateral development of water resources without the coordination and cooperation of other countries sharing the same water recourse may create conflict. Secondly, if one riparian country holds the geographical and military power, unbiased agreements are difficult to achieve. For example, Turkey is upstream and most of the water originates in its territory. Moreover, it has the most advanced military power (Priscoli and Wolf, 2009), giving it the upper hand in negotiations. As a consequence, Syria ended up in a Pareto-inferior situation because it did not ban the PKK earlier in the conflict which led to the signing of the Adana Agreement. The terms of the agreement include more things Syria has to give up in addition to banning PKK. For instance, Syria accepted Turkish rule over Hatay province, a long disputed land between the two countries. Syria publicly recognized Hatay as a Turkish territory after the Adana agreement, thereby losing two of its playing cards. The third lesson that can be garnered from the case in this paper is the vital role of third party intervention in resolving conflicts.

For the analysis part, the presented conflicts, especially the conflicts in both 1990 and 1998, can be seen as a single evolving conflict. This can serve as a base for methodology development. In addition, a more in-depth analysis could be carried out by mixing various approaches to conflict analysis. For instance, one can carry out hypergame analysis and coalition analysis at the same time for the 1990 conflict.

It is clear that the conflict along the Euphrates River is indeed a complex one. Bilateral and tripartite negotiations continue with mixed success. However, no solid agreement to date has been reached. This paper forms a strong base for carrying out an in-depth analysis of the present situation and determining how the conflict could evolve and what resolution could result in the future.

4.6 Chapter Summary

Chapter 5

Modeling Negotiations in Conflict Resolution Using Inverse GMCR

Although having a tool such as GMCR to predict and assess equilibria is important, real life conflicts require more than that. Studies show that 70 percent of all international conflicts since 1945 have involved third party intervention Bercovitch and Gartner (2006). These interventions strive to change the course of the conflict and ultimately reach a more desired resolution. The available models, including the standard GMCR, only predict the likely outcomes of the conflict. The many extensions of GMCR developed over the years aim to improve how GMCR predicts these outcomes. Another downside of the standard GMCR is the difficulty and subjectivity of the preference rankings of DMs in the conflict. Many GMCR extensions to enrich the preference ranking procedure have been developed, such as strength of preference Hamouda et al. (2004, 2006), preference uncertainty Li et al.

(2004a), and fuzzy preferences Bashar et al. (2012); Hipel et al. (2011).

In order to address the aforementioned shortcomings, an inverse GMCR is developed here. A main feature of this methodology is that it does not require preference information to model the conflict. This methodology can be utilized in many different ways. For instance, an intervener can use it to understand how to influence one or more of the disputants in a conflict. On the other hand, one of the disputants can utilize it to his advantage by understanding how competing parties could behave in order to achieve a desired resolution.

In addition to its use as a negotiation tool, inverse GMCR also can determine a more reliable prediction based on minimal preference ranking information. In GMCR, an analyst is usually confident about the most and least preferred states. The dilemma usually arises with preference rankings between these. Having a methodology such as inverse GMCR allows for exploration of all possible scenarios for unknown preference ranking ranges.

Although this paper focuses on inverse GMCR, three areas related to modeling third party intervention in conflicts that will be investigated, are as follows:

1. Inverse approach to conflict resolution (Inverse GMCR): A modeling technique that permits mediators to choose a desired outcome as an equilibrium, and works backwards to achieve it.

2. Inverse status quo analysis: An extension to the previous area that determines whether the desired equilibrium is reachable from the original state.

3. Third party strategy recommendations: A tool to analyze conflicts inviting mediation

and furnish insights as to the particular role a mediator should play to resolve the conflict.

5.1 Overview and Objective of Inverse GMCR

The Graph Model for Conflict Resolution (GMCR) forms an ideal framework to model and analyze conflicts; however, there are challenges to its applicability, especially in estimating the relative preferences of DMs involved in the conflict. In order to address this problem, inverse GMCR allows the analyst to determine how a desired resolution to the conflict can arise by generating all possible relative preferences that achieve it.

The premise of inverse GMCR is that the mediator needs a negotiation tool to influence the DMs. To be valuable, this tool should contain information about what motivates each party to undertake the selection of options leading to the resolution desired by the mediator. Therefore, mediators can focus their resources and strategies to guide the parties toward preferences that lead to this resolution. This tool is not just useful to third parties; stakeholders may be able to take advantage of it to influence their opponent(s).

The current GMCR framework, which forms the basis for inverse GMCR, requires preference ranking information that may not be easy to obtain. Inverse GMCR introduces a modeling approach that requires minimal ordinal preference ranking information up front. A desired resolution, or equilibrium, is decided and a list of preference ranking information leading to the resolution is generated. Thus, inverse GMCR utilizes GMCR as a negotiation tool rather than a prediction tool.

The main objectives of inverse GMCR are the following:

- Allow a third party to determine a desired resolution and understand how to achieve it
- Produce strategic information that will help mediators to influence the DMs involved in the conflict
- Give a range of preference rankings that measures the robustness of the conflict resolution

In contrast, the current GMCR methodology informs the user only about the possible resolution of a conflict based on the input preferences. Inverse GMCR explains how this resolution can be reached. Although the development of this approach was motivated by the need to facilitate third party intervention, other DMs involved in the conflict can also use it. Thus, it will allow for strategic negotiation based on tactical information to achieve a desired outcome.

5.2 Procedure and Implementation

The main difference between inverse GMCR and the standard GMCR procedure is in the order of steps. Figure 3.1 illustrates the current procedure for applying GMCR in the real world. A modified version, shown in Figure 5.1, illustrates how to apply inverse GMCR. The original procedure requires the following inputs for the conflict to be analyzed Fang et al. (1989, 1993):

- Decision makers (DMs)
- Options for each DM
- Infeasible states (such as mutually exclusive situations)
- Allowable transitions
- Relative preferences

On the other hand, inverse GMCR does not require the ranking of states for all DMs. Its requirements are:

- Decision makers (DMs)
- Options for each DM
- Infeasible states (such as mutually exclusive situations)
- Allowable transitions
- Desired resolution

The result will be a list of possible state rankings that will make the desired resolution stable under the selected stability definition.

In order to formally define the *inverse approach to GMCR*, one needs to furnish some definitions and notation. First, we show how a DM's preferences can be represented using an ordinal payoff vector.

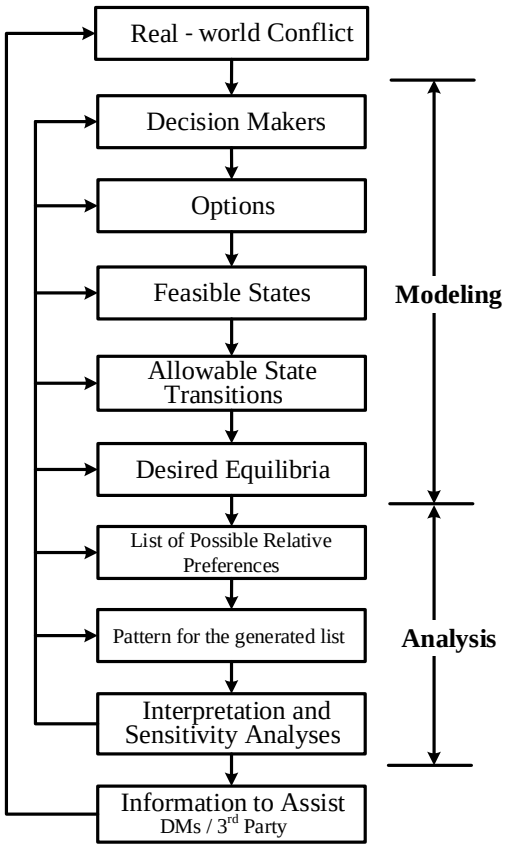

Figure 5.1: Inverse GMCR procedure in a real world conflict (modified from Fang et al. (1993))

Definition 5.2.1. The ordinal payoff vector of DM i, denoted by P_i, is

$$p^i = P_i = (p_1^i, p_2^i, \ldots, p_m^i), \quad P_i \in \mathbb{R}^m$$

If $s_a, s_b \in S$, then DM i prefers s_a to s_b or is indifferent ($s_a \succsim_i s_b$) *iff* $p_a^i \geq p_b^i$. An equivalent notation is

$$P_i(s_j) = p_j^i$$

so that $s_a \succsim_i s_b$ *iff* $P_i(s_a) \geq P_i(s_b)$

For example, if $P_i = (5, 0, 6, 2, 6)$ then the ordinal payoff value for DM i for state 1 is equal to 5. Thus, $P_i(s_1) = 5, P_i(s_2) = 0, P_i(s_3) = 6, P_i(s_4) = 2$, and $P_i(s_5) = 6$. Because preferences are assumed to be transitive, the payoff vector can be translated into a preference profile. A preference ranking for DM i is a list of feasible states ordered from most to least preferred for DM i, where ties are allowed. In the previous example, the preference ranking for DM i would be $PR_i = s_3 \sim s_5 \succ s_1 \succ s_4 \succ s_2$.

Note that the same preference ranking can be represented by many different ordinal payoff vectors. Two such ordinal payoff vectors are called *equivalent*.

Definition 5.2.2. If $p^i \in \mathbb{R}^m$ is an ordinal payoff vector for DM $i \in N$, then $(p^1, p^2, \ldots, p^n) \in \mathbb{R}^{mn}$ is a preference profile.

Inverse GMCR will be defined using both ordinal payoff vectors and preference profiles. In the graph model, analysis means finding all equilibria given a preference profile. In inverse GMCR, the problem is to find all preference profiles under which a given state

is an equilibrium with respect to a selected stability definition. After the introduction of preference profiles, a graph model can be denoted $G = \langle N, S, P \rangle$ where N is the list of DMs $N = \{1, \ldots, n\}$, S is the set of feasible states $S = \{s_1, s_2, ..., s_m\}$, and P is the preference profile $P \in \mathbb{R}^{mn}$.

The *inverse problem* for a desired equilibrium state $s_E \in S$ is to find all $p \in \mathbb{R}^{mn}$ such that state s_E is stable for all DMs if the preference profile is p.

Inverse Nash problem for s_E: Find $p \in \mathbb{R}^{mn}$ such that $s_E \in Nash(G)$ where $G = \langle N, S, P \rangle$

Inverse SEQ problem for s_E: Find $p \in \mathbb{R}^{mn}$ such that $s_E \in SEQ(G)$ where $G = \langle N, S, P \rangle$

Inverse GMR problem for s_E: Find $p \in \mathbb{R}^{mn}$ such that $s_E \in GMR(G)$ where $G = \langle N, S, P \rangle$

Inverse SMR problem for s_E: Find $p \in \mathbb{R}^{mn}$ such that $s_E \in SMR(G)$ where $G = \langle N, S, P \rangle$

A more formal definition according to each solution concept will follow.

5.2.1 Algorithms

In order to implement inverse GMCR, two approaches were investigated. The first was the brute-force method. As the name suggests, this method tests each possible preference profile for each DM against the desired equilibrium. Since the number of possible preference rankings is fairly large, a decision support system was designed to test the concept. The

$$IPV(s_E) = \left\{ \begin{array}{cccc} [{}^1p_1^1, {}^1p_2^1, \ldots, {}^1p_m^1] & [{}^1p_1^2, {}^1p_2^2, \ldots, {}^1p_m^2] & \ldots & [{}^1p_1^n, {}^1p_2^n, \ldots, {}^1p_m^n] \\ [{}^2p_1^1, {}^2p_2^1, \ldots, {}^2p_m^1] & [{}^2p_1^2, {}^2p_2^2, \ldots, {}^2p_m^2] & \ldots & [{}^2p_1^n, {}^2p_2^n, \ldots, {}^2p_m^n] \\ \vdots & \vdots & \ddots & \vdots \\ [{}^Tp_1^1, {}^Tp_2^1, \ldots, {}^Tp_m^1] & [{}^Tp_1^2, {}^Tp_2^2, \ldots, {}^Tp_m^2] & \ldots & [{}^Tp_1^n, {}^Tp_2^n, \ldots, {}^Tp_m^n] \end{array} \right\}$$

Figure 5.2: Representation of the inverse preference profiles list for state s_E

number of iterations required for a model, assuming strict ordinal preferences, is given by $(m!)^n$ where m is the number of feasible states and n is the number of DMs. If the combination of preference vectors for all DMs (i.e. preference profile) achieves the desired equilibrium, it will be saved into a list. The second algorithm was designed after observing the pattern produced by the brute-force method. It was clear that results followed certain rules which can be defined more formally, as outlined in the following subsections.

5.2.2 Inverse Nash Equilibrium

Definition 5.2.3. State s_E is a Nash equilibrium *iff* $p_i(s) \leq p_i(s_E)$ for all $i \in N$ and all $s \in R_i(s_E)$

Thus, inverse GMCR should produce all preference profiles that make the desired state s_E a Nash equilibrium. For illustration, inverse GMCR list according to preference profiles (or payoff vectors), denoted by $IPV(s_E)$, is shown in Fig 5.2. Note that each of the T rows is a preference profile, a combination of ordinal payoff vectors, that will make state s_E stable for all DMs. The possible number of profiles is denoted by T.

Note that ${}^{h}p_j^i$ is player i's ordinal payoff for state j in profile h.

Definition 5.2.4. A *Nash* $IPV(s_E)$ is a list of preference profiles, $p \in \mathbb{R}^{mn}$, where in each profile, for all $i \in N$, all $q \in R_i^+(s_E)$ satisfies $P_i(q) \leq P_i(s_E)$.

5.2.3 Inverse SEQ Equilibrium

Definition 5.2.5. An *SEQ* $IPV(s_E)$ is a list of preference profiles, $p \in \mathbb{R}^{mn}$, such that for each state $q \in R_i^+(s_E)$ in the preference profile, there exists at least one state $k \in R_{N-i}^+(q)$ satisfying $P_i(k) \leq P_i(s_E)$ for all $i \in N$

In other words, the combination of payoff vectors must ensure that for each UI a DM can take, there exists at least one sanction that will put the original player in a less preferred state. Please note that the notation $N - i$ means all DMs other than i.

5.2.4 Inverse GMR Equilibrium

Definition 5.2.6. A *GMR* $IPV(s_E)$ is a list of preference profiles, $p \in \mathbb{R}^{mn}$, such that for each state $q \in R_i^+(s_E)$ in the preference profile, there exists at least one state $k \in R_{N-i}(q)$ satisfying $P_i(k) \leq P_i(s_E)$ for all $i \in N$

5.2.5 Inverse SMR Equilibrium

Definition 5.2.7. An *SMR* $IPV(s_E)$ is a list of preference profiles, $p \in \mathbb{R}^{mn}$, such that for each state $q \in R_i^+(s_E)$ in the preference profile, there exists at least one state $k \in R_{N-i}(q)$ satisfying $P_i(k) \leq P_i(s_E)$ and all $h \in R_i(k)$ satisfy $P_i(h) \leq P_i(s_E)$ for all $i \in N$

5.3 Inverse Status Quo Analysis

Every real world conflict has a starting point from which the conflict evolves. This point or state is called *status quo* Fang et al. (1993). Depending on the status quo, a potential equilibrium may or may not be reached.

Li et al. developed algorithms and formal definitions to inspect the attainability of a potential resolution (*equilibrium*) from a certain state (*status quo*) Li et al. (2004b, 2005). An inverse approach to determine the required starting points in order to attain a desired equilibria is achieved by tracking the evolution of the conflict backward from a desired equilibrium to the status quo states.

5.4 Third Party Strategy Recommendations

Various third party roles and strategies are investigated and presented in another paper by the authors Kinsara et al. (2012) . Several methodologies are developed to determine the best role and strategy a mediator should undertake in any particular conflict situation. The motivation to introduce such a methodology is to operationalize the notion of third party intervention.

5.5 Decision Support System

The introduction of inverse GMCR makes the need for a decision support system obvious. Solving problems by hand is possible but tiresome, time consuming, and error-prone. First,

a code to test each preference profile was developed. This is called the Brute-Force method.

The matrix approach to GMCR allows for faster processing (Xu et al., 2009). The last decision support system, GMCR II, was developed by Xiaoyong (John) Peng in 1999 (Peng, 1999; Fang et al., 2003a,b). Until recently, no significant update was made to the decision support system, even though the program had issues that sometimes caused it to crash or display error messages.

A project to combine both the logical and matrix approaches into a robust and flexible decision support system was initiated by Rami Kinsara and Oskar Petersons. The objective of this system was to overcome the limitations of the previous version and also add new extensions and capabilities that it did not support. A main objective of the new system is to include the inverse GMCR methodology. Chapter 6 discusses in detail all aspects of the new DSS.

5.6 Application

5.6.1 Standard GMCR Results

The water conflict between Syria and Iraq in 1975 is explained in Section 4.1.1. In order to illustrate the inverse GMCR, this conflict will be re-investigated.

The standard GMCR analysis for this conflict is provided in detail in Section 4.2. As mentioned earlies in this research, standard GMCR requires preference information (or ranking of states). Since this model is fairly small, it is not difficult to derive the preference

information from the conflict background, although it remains subjective. The ranking of states for this conflict is shown in Table 4.6. Running the GMCR standard analysis predicts the most likely outcome in terms of equilibria based on the input preferences. Table 4.9 shows the equilibrium results according to different behavior patterns. Nash and Sequential Stability (SEQ) are the strongest stability definitions, meaning that DMs are not motivated to deviate from a particular state if the conflict reaches it. General Metarationality (GMR) and Symmetric Metarationality (SMR) are not as strong. More formal definitions and the relationships among the different stability definitions are mentioned earlier and can be found in Fang et al. (1989).

The objective of the standard GMCR analysis is to determine the equilibrium states, the states from which no DM is motivated to move. Therefore, once an equilibrium is attained, the conflict will probably end there. As mentioned in the historical background, the conflict reached state 6 in which both Syria and Iraq go to war, a strong equilibrium as shown in Table 4.9.

The standard GMCR methodology lacks the ability to determine a more desired resolution and explain how it can be achieved. This example also illustrates the subjectivity in determining the ranking of states.

5.6.2 Inverse GMCR Results

The goal of any intervention is to bring about a better resolution for all parties to the conflict. Inverse GMCR acts as a negotiation tool allowing the analyst to determine a more desirable resolution. In this particular case, a more desired resolution would be state

2 in which both Syria and Iraq stop escalating and water is released to Iraq. The objective of inverse GMCR is to provide mediators with strategic information in order to help them focus their efforts effectively and efficiently. Here, the mediation aims to influence Syria to release water and stop escalating. Using inverse GMCR, state 2 is chosen as a desired equilibrium and the decision support system was used to run the analysis. The findings indicate that 240 possible preference profiles can achieve the desired resolution. After analyzing these results, two meaningful patterns were identified that lead the conflict to the desired equilibrium:

- If Syria has state 2 as the most preferred state (Nash Stability)
- If and only if Syria prefers states 4, 5, or 6 to state 2 (Sequential Stability)

In other words, state 2 will be the resolution to the conflict if and only if (1) Syria prefers not to escalate or (2) being attacked by Iraq is less preferred for Syria. Having this strategic information could be vital to the mediators as they focus their efforts on influencing Syria to change its preference rankings. Consequently, the final outcome of the conflict would change.

The diagram in Figure 5.3 illustrates the inverse status quo tree in which state 2 is clearly reachable from state 6. Usually, when all moves in a conflict are reversible, states can be reachable using all DMs level. However, this tool becomes very valuable when irreversible moves are introduced to a conflict.

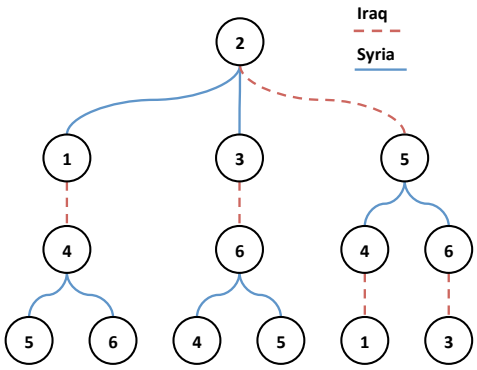

Figure 5.3: Inverse Status Quo Diagram for the Syria-Iraq conflict

5.6.3 Conclusions and Insights

The historical evolution of the conflict is illustrated in Table 5.1. Note that state numbers with an asterisk (*) indicate mediation. In inverse GMCR context, a mediator (or Iraq) can influence Syria in two ways:

- Making the escalation option for Syria less preferred
- Making the attack option by Iraq disastrous for Syria

DM	Option	Status Quo	Intermediary States			Equilibrium
Syria	Release Water	N	N	N	N →	Y
	Escalate	N	N →	Y	Y →	N
Iraq	Attack	N →	Y	Y	Y →	N
Third Party	Act	N	N	N →	Y	Y
Label		1	4	6	6*	2*

Table 5.1: Historical evolution of the 1975 conflict

In this conflict, Saudi Arabia mediated the conflict by contributing to a basin fund that would finance irrigation reform Akanda et al. (2007). Therefore, escalation by Syria

became less preferred as it risked losing this fund, in addition to other factors related to international pressure and war costs.

This conflict emphasizes how third party intervention can change the course of the conflict and bring about a better resolution. Studies show that 70 percent of all international conflicts since 1945 have involved mediation Bercovitch and Gartner (2006). The strategy of intervention is as important as the intervention itself if not more. Therefore, a tool to provide insights on how to achieve a desired resolution is valuable. Inverse GMCR is a strategic tool that utilizes GMCR as a negotiation tool rather than as a prediction tool. Moreover, its information requirements are minimal.

5.7 Chapter Summary

Chapter 6

Comprehensive Decision Support System

The introduction of the inverse approach makes the need for a decision support system obvious. Solving problems by hand is possible but tiresome, time consuming, and error-prone. First, a code to test each preference profile was developed. This is called the Brute-Force method The matrix approach to GMCR allows for faster processing (Xu et al., 2007; Xu, 2009). The last decision support system, GMCR II, was developed by Xiaoyoung (John) Peng back in 1999 (Peng, 1999). Until recently, no significant update was made to the decision support system, even though, the program had issues that sometimes caused it to crash or display error messages. A project to combine both the logical and matrix approaches into a more robust and flexible decision support system was initiated by Oskar Petersons and Rami Kinsara under the supervision of Prof. Keith Hipel and Prof. D. Marc

Kilgour. The objective of this system is to overcome the limitations in the previous version and also add new extensions and capabilities that it did not support. A main objective of the new system is to include the inverse approach methodology. An important feature of the software is the ability to narrate the output results. More extensions and features are planned.

6.1 Conflict Specification

6.1.1 Option Objects

Option Name

Reversibility

6.1.2 Condition Objects

6.1.3 Infeasible Conditions

6.1.4 DM Objects

DM Name

Options Controlled

Preference

6.2 Conflict Data Processing

6.2.1 Removing Infeasible States

6.2.2 Preference Prioritization

6.2.3 Direct Ranking Handling

6.2.4 Reachability Matrix

6.3 Analysis Engines and Output

Logical Solution

Chapter 7

Conclusions

In addition to the methodologies presented in this proposal, several important topics are outlined in the following sections and will be investigated. These topics fall within third party modeling in conflict resolution. Various third party roles and strategies are investigated and presented in Chapter 2 of this proposal. A methodology is needed to determine the best role and strategy that a mediator should undertake in any particular conflict situation. The motivation to introduce such a methodology is to operationalize the notion of third party intervention.

Although basic features of the inverse approach are outlined in this proposal, further enhancements are planned to extend the capability and usefulness of the methodology. One area being studied is the development of a cost and payoff extension to the inverse approach to GMCR. This feature will allow for narrowing down the list of possible profiles and will allow for more relevant and meaningful results.

An inverse approach to determine the required starting points in order to attain desired equilibria will be investigated. This will be achieved by tracking the evolution of the conflict backward from a desired equilibrium to the status quo states.

As mentioned earlier, with the introduction of the inverse approach, a more in-depth model for sensitivity analysis that determines the robustness of any equilibrium by outlining the range of preference profiles in a conflict will be put forward.

Work has already started on a new decision support system using both the logical and matrix approaches for GMCR calculations. The new decision support system has the capability to perform basic inverse approach calculations using the definitions presented herein. In addition, the software will have the capability to perform regular and inverse status quo analysis. It should be noted that extensions made to the graph model for conflict resolution can be easily embedded into the new decision support system.

In order to better understand and appreciate the insights of the proposed methodologies, real world examples will be analyzed and investigated. The intention is to apply the methodologies to different conflict types, including political, environmental, and business conflicts. The research goals and approximate completion dates are summarized and outlined in Table 7.1 below.

Research Milestone	Scheduled Completion
The presentation of the comprehensive report. This include the research objectives and a detailed clarification of the work that should be completed during my PhD degree	May, 2013
Fine-tune the methodology for the inverse approach to GMCR and apply it to different examples. This also include submitting a journal paper about the subject	September, 2013
Develop a cost and payoff extension to the inverse approach to GMCR and submit a paper about the subject	December, 2013
Develop a tool to operationalize and determine the best role and strategy for mediators to undertake in different conflict situations	February, 2014
Develop an inverse approach status quo analysis methodology	April, 2014
Establish a framework for in-depth sensitivity analysis allowing for preference profile ranges using the inverse approach	May, 2014
Submitting papers about each methodology after applying them to different real world conflicts	Ongoing
Seminar presentation	October, 2013
Thesis writing and completion	September, 2014

Table 7.1: Research Milestones and Schedule

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