A Multi-Stage Graph Model Analysis

for the International Toxic Waste Disposal Conflict

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

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Abstract

A generic conflict model is developed to analyze international toxic waste disposal issues, and then, to provide feasible strategic resolutions for this serious environmental dispute. With the rapid growth of the global economy, toxic waste traffic from the advanced to developing nations has become a serious side effect of this globalization. The illegal transboundary movement of toxic wastes not only aggravates the burden on the poorer nations, but also negatively impacts the worldwide environment.

In this thesis, the ongoing toxic waste disputes are divided into two stages consisting of the dumping prevention and dispute resolution stages. The analyses based on the methodology of Graph Model for Conflict Resolution are used in both stages in order to grasp the structure and implications of the conflict from a strategic viewpoint. The in-depth modeling of the toxic waste dumping disputes, which consist of historical and generic situations, specifies the involved parties and their options. By synthesizing the economic, political and legal factors, the relative preferences for each party can be determined. The Graphical User Interface (GUI) of the Decision Support System (DSS) GMCR II simplifies the processing of calculations. The analytical research furnishes investigators or other interested parties with possible resolutions for the disputes arising from an international waste dumping event. Sensitivity analyses are also conducted to provide a comprehensive understanding of the different situations that may occur in real-world cases. The case study of the Ivory Coast waste dumping controversy is used to demonstrate how to practically implement the generic multi-stage graph model.

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Chapter 1 Introduction

The international dumping of toxic waste in developing countries by developed nations has become a serious situation, which has generated significant concerns among nations around the globe. In response to this grave concern, a generic graph model has been developed for the modeling and analysis of the resulting international toxic waste disposal negotiation problem. This model provides investigators or other interested parties with a framework for formally analyzing disputes arising from an international waste dumping event. Based upon information collected from involved parties, possible resolutions are furnished. Due to the variety of situations that may occur in actual cases, sensitivity analyses are also provided. After a strategic investigation of the Ivory Coast Waste Dumping case in August 2006, some conclusions and discussions are addressed.

1.1. International Toxic Waste Disposal

International toxic waste disposal has become a by-product of industrialization and globalization. This past century witnessed an increasingly globalized economy. As evidence of this global activity, the World Trade Organization (WTO), successor to the

General Agreement on Tariffs and Trade (GATT), was established in 1995 (UN Integrated Regional Information Networks, 2006). However, negative side effects, such as widespread groundwater and food chain pollutions, have unfortunately been generated.

In the second half of the twentieth century, along with the rapid development of technology, the disposal of wastes, especially hazardous wastes, has become a major burden for highly advanced countries. At the same time, people have come to realize the importance of living in harmony with their natural environment. Hence, regulations and laws related to environmental protection finally came into effect in these countries (Tolba, 1990). Consequently, the costs of the disposal of hazardous wastes dramatically rose along with the corresponding compliance with these laws. Driven by profits, industrialists began to seek lower-cost ways to dispose of toxic wastes.

Obviously, weakly governed developing countries gradually became the most popular targets for toxic waste dumping and the least costly alternative to solving the toxic waste problem. Sadly, numerous toxic waste traders transferred huge volumes of hazardous wastes from richer nations to poorer ones with a contagion of the NIMBY (not-in-my-backyard) syndrome (Asante-Duah, 1998). Consequently, the transboundary movement of hazardous wastes escalated beyond control throughout the 1980s (Secretariat of the Basel Convention, 2006).

As a number of scandals and tragedies began to reveal the scope of this problem, people eventually woke up to the situation, and endeavored to find practical solutions to prevent the continuation of this outrage against the environment. After Non-Governmental Organizations (NGOs) campaigned against this illegal trafficking, the

United Nations (UN) authorized its United Nations Environment Programme (UNEP) to take practical action. In March of 1989, 118 countries signed the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal, which went into force in May, 1992. As of July, 1997, 113 countries had ratified the treaty (Secretariat of the Basel Convention, 2006). The Basel Convention drew up the principles of environmentally sound and efficient management, in order to achieve the final goal of protecting human health and the environment from hazardous wastes (United Nations Environment Programme, 2002). It not only established a legislative mechanism to control the transportation of international hazardous wastes, but also furnished detailed and practical provisions in managing the transboundary movement between the parties of the Convention. To facilitate the implementation of the Convention, parties are required to designate competent authorities who will provide prior written notification for any hazardous waste movement. Furthermore, the Convention requires the nation of export, or generator, or exporter to provide prior written notification to the competent authority of the nation of import. All export may only take place with the prior written consent from the nation of import and transit (Secretariat of the Basel Convention, 2006). The Basel Convention is not only a milestone in international environmental law, but also a significant breakthrough against illegal trafficking in hazardous wastes.

Nevertheless, as a voluntary agreement, the Basel Convention applies only to those parties who signed the treaty and, therefore, remains unheeded by those countries that rejected it. Unfortunately, some heavily industrialized countries, such as the United States, refused to sign the Basel Convention (Secretariat of the Basel Convention, 2006).

In addition to this limited jurisdiction, the treaty has an inherently weak control mechanism due to the principle of "Prior Informed Consent", which has led to numerous "legal" transboundary movements of hazardous wastes that are labeled as having "Competent Authority". Moreover, the particular political structure of the UN means the inevitable overlap of the jurisdictional solutions between the Multilateral Environmental Agreements (MEA) and the Free Trade Agreements (FTA). This complexity has diminished the strength of international environmental law (Puckett, 1997).

1.2. Motivation of the Research

Because of the complex nature of the international toxic waste dumping problem as was discussed in the last section, a practical and efficient methodology is required to examine and resolve it. The Graph Model for Conflict Resolution (GMCR) (Fang et al., 1993) is a novel approach to model and analyze strategic conflict. As an expansion of conflict analysis (Fraser and Hipel, 1984), GMCR provides an easy-to-use and flexible methodology for strategic conflict analysis, and differs from the technique of classical non-cooperate game theory (Von Neumann and Morgenstern, 1944). In this thesis, by breaking down the toxic waste dumping problems into two main stages, the dispute prevention stage and the dispute resolving stage, complicated conflict situations are readily investigated, better understanding of past events realized, and possible outcomes for ongoing conflicts forecast.

1.3. Organization of this Thesis

Figure 1.1 outlines the structure for this thesis. In the forthcoming chapters three series of fundamental questions are discussed to clearly explain the research that is presented within the thesis.

- *What is international toxic waste dumping? Who are involved in the dispute? Why is it so important to analyze this type of dispute?* The answers for this first series of questions are explained in Chapters 2 and 3. More specifically, Chapter 2 focuses on the technical and historical aspects of toxic wastes and the transboundary movements of toxic wastes. Their relationship with the global economy and politics is also stated. Chapter 3 analyzes in detail various dispute situations, especially the parties involved and their objectives and responsibilities.

- *What is the methodology used in this thesis? What is the basic idea of this methodology? Is it an appropriate tool for addressing this toxic waste problem?* Chapter 4 introduces the Graph Model for Conflict Resolution, where it is used to investigate and resolve international toxic waste dumping disputes. Advantages and other important aspects of this methodology are discussed. A practical decision support system, GMCR II, used to apply the methodology to practical problems, is presented at the end of the chapter.

- *How is the dispute modeled? How is the analysis carried out? Can this kind of analysis be utilized in practice?* In Chapters 5 and 6, the generic multi-stage graph model is proposed. By applying the model to a real world toxic waste dumping case, the Ivory Coast toxic waste dumping scandal, the practicality and effectiveness of the

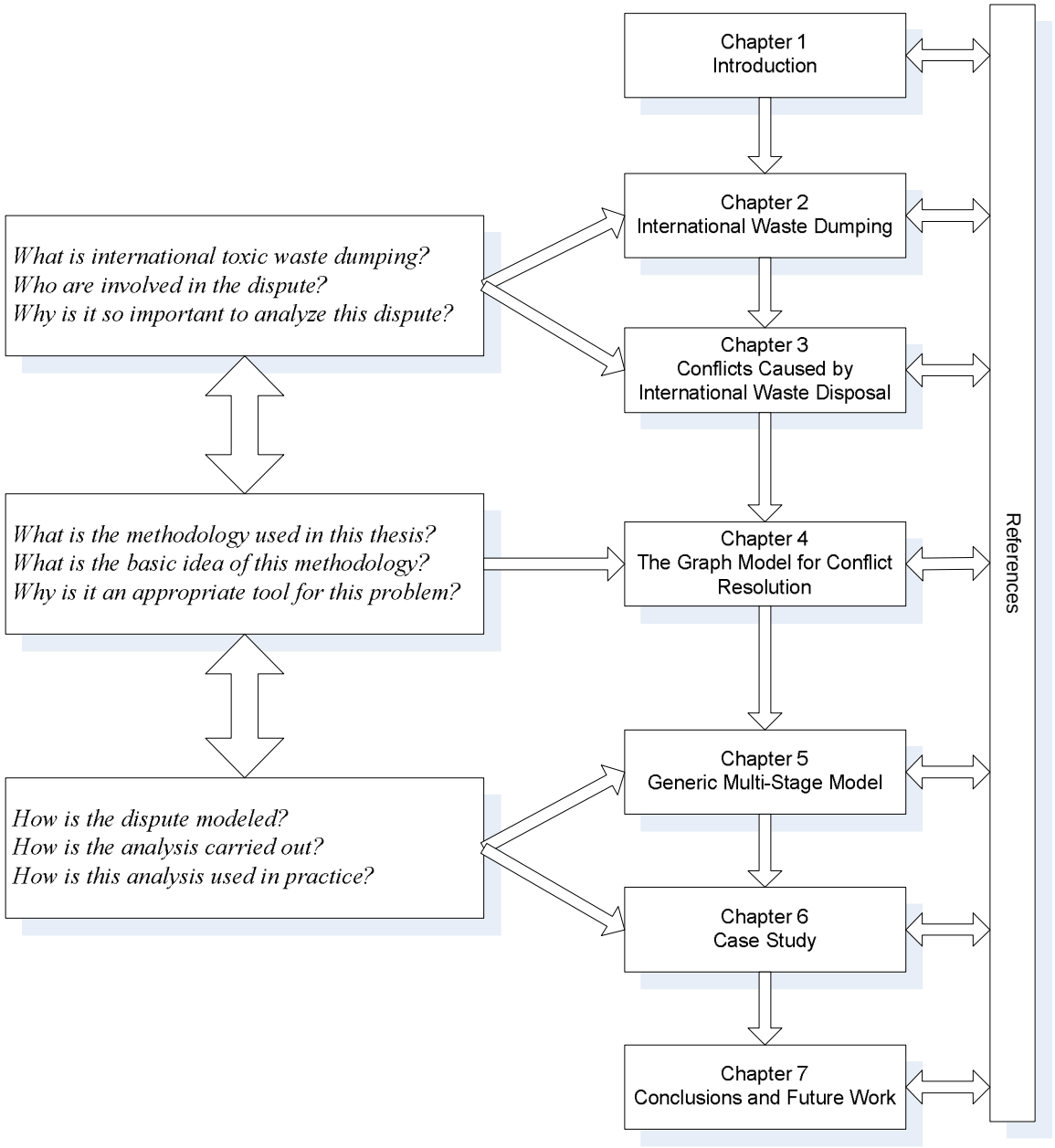

Figure 1.1. Organization of the Thesis

model are illustrated and proven.

The thesis concludes by summarizing highlights and some suggestions for future investigations.

1.4. Summary

This chapter started with a brief introduction of the international toxic waste disposal problem, and highlighted the methodology of the Graph Model for Conflict Resolution and its realistic significance for investigating this serious type of issue. Then, the organization of this research is explained and depicted in Figure 1.1.

Chapter 2 International Toxic Wastes Disposal

The twentieth century was considered a new era of modernization in human civilization. Following World War II, peace and development, instead of colonialism, became the mainstream priority throughout the world. At that time, most countries started to concentrate on the building of regimes and the development of their economies, which then contributed to the tremendous driving force motivating human civilization to move forward. Along with the development of new technologies, new materials were being refined and improved. Also at this time, new industries were born, such as the petrochemical, biochemical, and nuclear industries, and, as well, conventional industries were enriched. Simultaneously, rapid industrial growth and incredible efficiency were present in many nations. However, all things may be viewed from two perspectives. The overexploitation of natural resources damaged the environment of the local populace, and extensive agricultural and industrial production increased wastes. It became necessary to dispose of various wastes to eliminate the negative side effects of the new technologies. Many of these wastes were toxic, non-recyclable and capable of causing permanent contamination and damage to the environment. Due to these disastrous impacts on the environment and the high cost of the disposal of these toxic wastes, many

nations transferred this heavy burden to other nations in order to protect their domestic environment. Over the past decade, the international dumping of toxic wastes has become even more widespread and as a result, attracted serious critical attention and concern.

2.1. What are Toxic Wastes?

2.1.1. Definitions and Classification

While entering a new era in human history, to meet the swelling demand caused by the booming global population, people were forced to increase production capabilities. Numerous new technologies were adopted in the production activities of human beings. Although the technological innovations have improved the quality of their lives, people have come to rely on technologies and the resulting exploitation of natural resources. The extent of this exploitation and the abuse of new technologies have caused an energy and environmental crisis. A tremendous amount of hazardous waste has been produced annually. Figure 2.1 illustrates the amount of hazardous wastes generated from 1993 to 2000.

As a multidimensional term, the definition and classification system of hazardous wastes is composed of a set of mixed criteria from Chemistry and Environics. In order to avoid any confusion, this research adopts the definition and classification system from the Basel Convention, which is used to determine the type of waste (Secretariat of the Basel Convention, 1989).

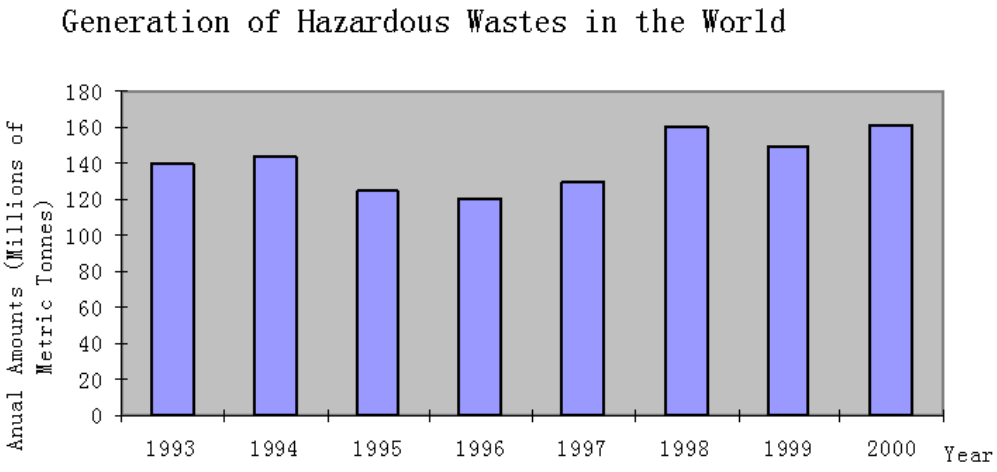

Figure 2.1. Worldwide Generation of Hazardous Wastes
(Secretariat of the Basel Convention, 2002)

- **Type I**: These wastes, which need to be controlled, consist of the two main categories and relevant sub-categories. The categorization of these types of wastes is explained in Table 2.1.
- **Type II**: These wastes require special consideration, and consist of wastes and residues from common households.
- **Type III**: These wastes are defined as hazardous. Table 2.2 presents a list of hazardous wastes and their characteristics. The wastes that contain one or more of the characteristics listed in this table would be considered hazardous. The details of these categories can be found in Annex I, II, and III of the Basel Convention.

Table 2.1. Type I Wastes Categorization

Category I	1) Clinical usage.
	2) The production and formulation of pharmaceutical, biocides, and organic solvents.
	3) Chemical substances containing polychlorinated biphenyls (PCBs), polychlorinated terphenyls (PCTs), and/or polybrominated biphenyls (PBBs).
Category II	1) The heavy metal elements and compounds, such as: Beryllium, Copper, and Zinc.
	2) Organic compounds, such as: Phosphorus, Cyanides, and Phenols.

Table 2.2. List of Hazardous Characteristics
(Adapted from Annex III of the Basel Convention)

UN Class	Code	Characteristics	Description
1	H1	Explosive	Explosive substances
2	H3	Flammable Liquids	Liquids with strong volatility
4.1	H4.1	Flammable Solids	Solids with strong volatility
4.2	H4.2	Flammable	Spontaneous combustible substances
4.3	H4.3	Flammable	Substances with flammability in contact with water
5.1	H5.1	Oxidizing	Substances with oxidizability
5.2	H5.2	Organic Peroxides	Organic unstable substances with exothermic self-accelerating decomposition
6.1	H6.1	Poisonous	Substances cause death and serious injury through various routes of entry
6.2	H8	Infectious	Substances contain pestiferous bacterium, viruses
8	H10	Corrosives	Cause severe damage to living organisms due to contact or leakage
9	H10	Toxic Gas	Liberation of toxic gas interaction with air or water.
9	H11	Chronic Toxic	Substances with chronic effects on human health
9	H12	Ecotoxic	Exposure to toxic substances leads to bioaccumulation
9	H13	Produce	Can produce any of the substances listed above after disposal

2.1.2. Environmental Effects

Hazardous substances possess the chemical and biochemical characteristics that dictate the dangers of these materials. Hazardous wastes can be roughly further classified into the following classes by:

(1) heavy metal elements;

(2) flammable substances, whose explosion can be considered as a sort of acute combustion;

(3) poisonous substances; and

(4) pestiferous substances.

From physical and chemical perspectives, many substances are synthetic compounds. These substances are extremely unstable, and tend to encounter an acute chemical interaction or volatilize during storage and transportation. They may not only damage the living organisms within a certain range, but also contaminate the air, soil, and water resources. Correspondingly, other substances exist stably as certain compounds.

People have opened a Pandora's Box by decomposing compounds into unstable states and distributing these unstable substances and their toxicities into the environment. For instance, heavy metal elements are generally poisonous and radioactive. Due to their chemical stability, also called durability, after being abandoned heavy metals can exist for years. They poison species by disrupting their cellular enzymes, which maintain the mineral metabolism of living cells. No matter how heavy metal elements enter the body of a species, they will damage normal life activities of the species through the bioaccumulation of toxicities. Moreover, the radioactivity of most heavy metals can

cause variations in species. According to Darwin's Evolution Theory, there are three basic processes required for evolution to take place:

(1) there must be some way for inheritability to occur;

(2) there must be variation; and

(3) there must be a natural selection.

Variation caused by toxicity may lead evolution in a wrong direction, and therefore, disturb the balance of ecosystems.

2.2. Transboundary Movement of Toxic Wastes

The progress of new technologies manifests itself not only in the applications of technologies but also in the changes of people's consciousness. With the growth of industrialization, people in industrialized countries came to realize the importance of environmental protection. As a prevalent disposal option for waste, landfill was not a feasible treatment for most of the hazardous wastes. People were not willing to risk their lives by having dump and landfill sites located where they live. In many industrialized countries, relevant environmental laws and regulations successively came into being. For instances, in 1969, the United States (US) launched the National Environmental Act and founded the US Environmental Protection Agency (EPA). The United Kingdom's (UK) Deposit of Poistionous Waste Act (DPWA) was implemented in 1972 (Asante-Duah, 1998). Highly industrialized countries established more advanced technological and industrial standards than less-industrialized nations, such as controls over utilization rates of resources, emission standards and disposal technologies.

Contrarily, most poor nations were in a difficult situation with weak governance due to historical and other reasons. Inadequate funds and fragile infrastructure cannot support an effective administration or law enforcement system. Therefore, industrialized countries legislated more strict environmental protection than poorer countries. The difference of environmental laws between rich and poor countries became one of the main reasons for the transboundary movement of hazardous wastes. Just like water stream's flow from higher ground to lower, hazardous wastes move from nations with more restrictive environmental laws to others with less restrictive environmental laws. Typically, the existed movement characterized two main directions of flows: from North to South and West to East. It was disclosed in 1988 that more than 1 million tonnes hazardous wastes were transported from West Europe to East Germany. These exporters included Austria, Belgium, France, Italy, the Netherlands, Switzerland, the UK and West Germany. Similar routes of hazardous wastes were also observed in the North America. As the neighbors of the US, most Latin American and Caribbean Countries readily became the recipients of the US hazardous wastes (Asante-Duah and Nagy, 1998).

However, the actual situation always becomes more complex when economical and political factors are considered, and thus, can never be viewed as the simple flow of a water stream. After it began in the 1970s, the transboundary movement of hazardous wastes dramatically increased throughout the following decades. Table 2.3 provides the number of schemes proposed for exports by receiving region and year.

This table shows the increasing tendency to import wastes into developing or less-industrialized regions. This data also illustrates the irregular development of these imports. Particularly of note is the increase from 1989 to 1990 suggesting a lack to the

response to the Basel Convention, but the remarkable decrease from 1992 to 1993 does reflect its influence after fully coming into force in 1992.

Table 2.3. Number of Schemes Proposed for Exports by Receiving Region and Year (Clapp, 2001)

Region	Year					Totals
	1989	1990	1991	1992	1993	
Baltics and Eastern/Central Europe	32	50	43	113	61	299
Africa	11	4	4	7	4	30
Pacific	1	4	1	2	4	12
East Asia	4	14	22	50	22	112
Southeast Asia	0	2	10	46	26	84
South Asia	2	3	2	24	12	43
Middle East	0	0	1	12	1	14
Latin America/Caribbean	27	42	30	32	16	148
Totals	77	120	113	286	146	742

The Organization for Economic Cooperation and Development (OECD) (1993b) estimated that "on average, a consignment of hazardous wastes crossed an OECD frontier every five minutes, 24 hours per day, and 365 days per year". Montgomery (1995) also stated that "officially, about 1 million tonnes, or 5-10 percent of hazardous wastes produced by the rich countries are legally traded". Actually, the reliability and consistency of data were extremely difficult to maintain in practice. For example, in the OECD countries, which possess the most advanced environmental management systems, success was only achieved in dealing with this problem on a domestic level (O'Neil,

2000). Although the records of tracing these movements were not reliably complete, they still revealed the rapidly increasing tendency that the hazardous wastes were flowing from developed to developing countries, as shown in Table 2.4.

Table 2.4. Number of Waste Trade Schemes from OECD to Non-OECD Nations (Clapp, 2001)

Year	Further use claimed	Final disposal	Total where fate/pretext is known	Fate/pretext unknown	Total of all schemes	Percentage of "further use" known schemes
1989	54	17	71	5	76	76%
1990	92	19	111	7	118	83%
1991	94	14	108	5	113	87%
1992	238	30	268	17	285	88%
1993	123	15	138	8	146	89%
Totals	601	95	696	42	738	86%

The United States, the largest hazardous waste generator, annually produces 80 percent of the world's hazardous wastes (Clapp, 2001). Figure 2.2 illustrates the rapid growth trend in the quantities of hazardous waste generation in the United States between 1970 and 1989.

This data may seem of little importance, but numerous highly notorious scandals have been exposed. For example, in December of 1987, a cargo ship dumped about 4,000 tons of ash, from a Philadelphia garbage incinerator labeled "soil fertilizer", near Gonaives, Haiti (Pellow, 2007). In addition, in 1988, a boatload of toxic Italian chemical waste was dumped in Koko, Nigeria (Basel Action Network, 2008).

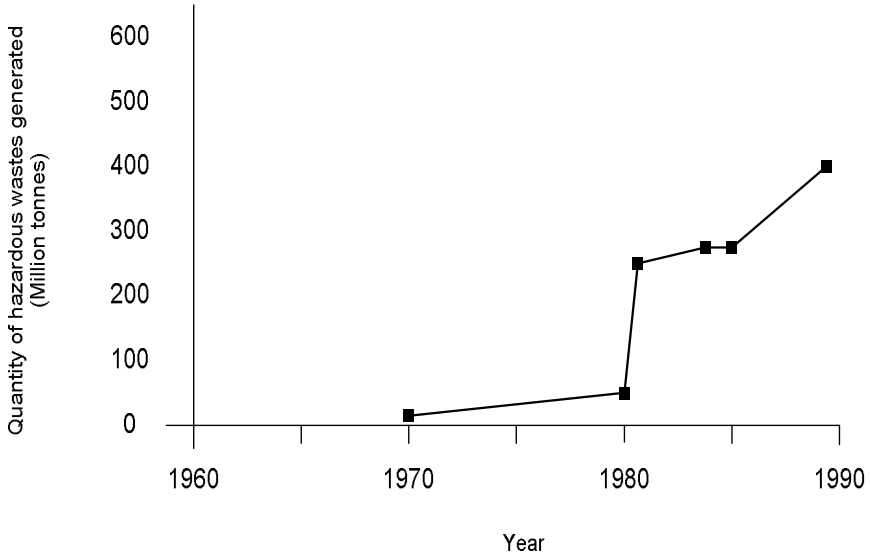

Figure 2.2. Trend in the Quantities of Hazardous Wastes Generation in the United States between 1970 and 1989 (adapted from Asante-Duah and Nagy, 1998)

Having experienced a period of disorder regarding the movement of international hazardous wastes, people had to recognize and respond to the serious consequences caused by this uncontrolled waste traffic. Many nations successfully established national level systems for controlling and monitoring the transboundary movement of hazardous wastes. These attempts finally propelled the adoptions of a series of multilateral agreements and international conventions. The Basel Convention of 1989, as a milestone in the history of international environmental law, established a legislative mechanism to control and prohibit the illegal international traffic of hazardous wastes. Details about the Basel Convention are further discussed in Chapter 4.

2.3. Relationships with the Global Economy and Politics

2.3.1. Establishment of the global waste trade market

In the last century, human civilization experienced the ravages of two world wars, which caused the global economy to recede. People were dedicated themselves to the recovery and redevelopment of the economy following the two world wars. These efforts brought a post war economic boom that resulted in industrial growth and an increase in generation of toxic wastes. Related environmental laws were enacted to protect public health, and required a compulsory treatment on hazardous wastes, which increased disposal costs. Because countries have different capabilities to treat toxic wastes, trader in toxic wastes took place among countries. The Netherlands, for example, was one of the first nations to trade in toxic wastes starting in 1969 (Asante-Duah and Nagy 1998).

2.3.2. Hazardous Waste Movement and the Global Economy

After a new international regime was established following the end of the Cold War, the global economy entered an era of renaissance. The establishment of the World Trade Organization (WTO) in 1995 was a significant landmark in the expansion of the global economy. The WTO's fundamental principles originated by GATT, which included: 1) freer trade, which minimizes the trade barriers to ensure the flow of commodities, and encourage trade, and, 2) non-discriminatory trade, which contains two aspects described as follows (World Trade Organization Information and Media Relations Division, 2007).

- Most-Favoured-Nation (MFN): treating other people equally. As a member of this trade system, countries cannot discriminate between their trading partners, and any state has to do the same for all other members.
- National Treatment: treating foreigners and locals equally. Products from importation and local manufacturers should be treated equally — at least after the foreign goods have entered the market.

These positive aspects of the Free Trade system contributed substantially to the development of the global economy. However, also due to the free trade market, hazardous wastes became a type of commodity. If the assumption of ignoring the environmental influence of hazardous wastes could be made, hazardous wastes trade could be considered as an extremely profitable business having a world wide market and beneficial to the global economy in a certain sense. For example, in the United States, the cost of landfill for hazardous wastes increased from US $15 per ton in 1980 to US $250 per ton in 1988 (Stronhm, 1993; Clapp, 2001). At the same time, in Africa, the cost was about US $40, or in some cases, as low as US $2.5 (Tolba, 1990; Clapp, 2001). Therefore, when the United States exported hazardous wastes, the cost of waste disposal would become substantially lower. Not only the waste exporter, but also the receiver would make profits. It seemed to be a win-win situation. However, this specific assumption has questionable validity because the negative environmental influences are so significant that they can never be neglected. To analyze the global economy, people must consider the significant impact of the environmental factors. Although impacts may not appear instantly, they will surface in the long term.

2.3.3. Hazardous Waste Movement and Global Politics

Hazardous waste movement reflects the bilateral and multilateral relation of the involved parties and reveals the contrast of the political strengths of nations. On one side, the rich nations not only dominate at the international political stage because of their outstanding economic, military and cultural factors, but also continue to enlarge their advantages by using all feasible methods. Transferring the heavy burden by dumping hazardous wastes to the poor nations is one of them. On the other hand, with the awakening of the developing countries, they united and struggled together for more advantageous positions in international relations. Nevertheless, globalization requires the formation of interdependencies between these two groups, which also has political implications (Schwenninger, 2003). In addition, with the mediation of the UN and participation of Non-Governmental Organizations (NGOs) in international affairs, a new type of multi-polarity has emerged in international politics (Wendt, 1993).

2.4. Impact on the Global Environment

Figure 2.3 demonstrates the known and suspected routes of international hazardous wastes trade. Hazardous wastes mainly travel from the most advanced countries, such as the US and the European Union (EU), to the less developed countries, like nations in Africa, Asia, Latin America and Eastern Europe.

Hazardous waste traffic crosses oceans and continents, to every developing nation location. The combination of long transport distances and the great volume of

transported hazardous waste results in large amounts of energy consumption and the emission of huge quantities of carbon dioxide and toxic gases, which, in turn, accelerate global warming. As well, the transportation routes cross oceans and continents, and are not secure due to geographical and climatic conditions. Accidents or leakage during transportation cause potentially catastrophic damage to the surrounding environment.

Figure 2.3. Known and Suspect Routes of Hazardous Waste Traffics

The movement of hazardous wastes is actually redistributing their geographical locations. This redistribution only serves to decrease the environmental contamination in the exporting countries. Globally, there is no elimination of hazardous waste, but in reality the production of more unnecessary wastes. Furthermore, lacking complete management systems and current disposal technologies for hazardous wastes, developing countries only adopt simple solutions, such as landfill and incineration, which result in

the hazardous substances inevitably contaminating the surrounding environment and spreading to other locations. Finally, if the activity of international waste dumping continues, the harm of hazardous wastes will react with the international environment through the global ecosystem.

2.5. Conflicts Caused by International Toxic Waste Disposal

Conflicts arise when interactions between antithetical forces become acute. The nations of export, import and transit interacted in the case of the international toxic waste disposal. Conflicts occurred because of these interactions. Chapter 4 of this thesis develops a generic multi-stage graph model to investigate the conflicts caused by international toxic waste disposal disputes. The detailed descriptions of the participants are also provided with applications.

2.6. Summary

This chapter begins with the introduction to the definition and classification system of hazardous wastes, and describes the chemical and physical characteristics of hazardous substances and their dangers. The history of hazardous waste dumping is then traced and the reason for its occurrence explored. Finally, economic and political perspectives provide further understanding of the conflicts caused by international waste dumping.

Chapter 3 The Graph Model for Conflict Resolution

The Graph Model for Conflict Resolution (GMCR) is a game theoretic methodology that can be used to analyze situations of disharmony existing everywhere in the real world (Fang et al., 1993). As an expansion of the metagame (Howard, 1971) and conflict analysis (Fraser and Hipel, 1984), GMCR provides investigators and researchers with an easy-to-use and flexible methodology for strategic conflict analysis (Fang et al., 1993). The Decision Support System (DSS) GMCR II is embodied with the core GMCR analysis engine and the friendly Graphical User Interface (GUI). The GMCR II assists users in all phases of modeling, analyzing and interpreting of strategic conflicts (Fang et al., 2003a, 2003b).

3.1. Decision Making under Conflict

As the only intelligent species on the earth, humans possess unique characteristics, which differentiate them from all other species. The human concept of self-awareness, their thought processes, and other distinct psychological characteristics over time, resulted in the birth of civilization and human society. The combination of the human social and competitive natures resulted in the development of religions, ethnicities,

differentiation and corresponding conflicts, which have prevailed throughout the history of civilized man.

Conflicts arise when the interactions between antithetical parties become acute. Generally, every involved party endeavours to maximize what he/she may gain in a conflict situation. This is a difficult challenge for all parties, deciding upon the options, which most benefit them. As a rational participant in the conflict, each party must analyze the situation, predict their rivals' possible preferred solutions and then prepare his/her own solution. Obviously, an intelligent and efficient method becomes vital to resolving this complicated and dynamic situation.

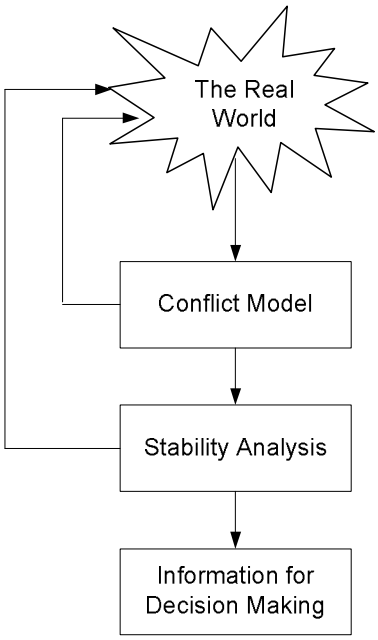

Figure 3.1. The General Conflict Analysis Process (adapted from Hipel, 2007)

Figure 3.1 illustrates a general conflict analysis process: starting with modeling the conflict, the redundant information is filtered and a complicated situation is transformed

into a precise mathematical model. Then, after conducting a stability analysis the resulting information is outputted to the involved parties for Decision Making. Numerous models have been developed to improve the conflict analysis methodology. These diverse models and perspectives have enhanced techniques and enlarged the scope of conflict analysis. Therefore, conflict analysis may be applied in situations ranging from strategic to tactical, unstructured to highly structured, qualitative to quantitative, and from soft systems to hard systems (Figure 3.2).

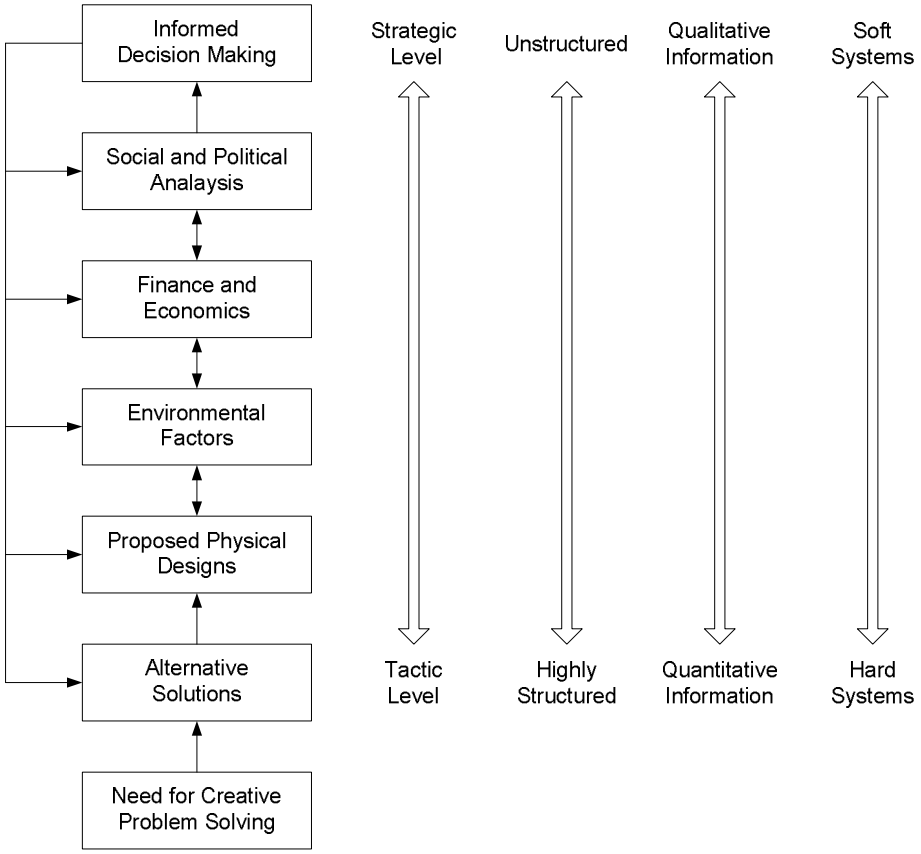

Figure 3.2. Engineering Decision Making (adapted from Hipel, 2007)

The conflict model is a non-quantitative approach to Game Theory. Classical publications of Game Theory include Von Neumann (1928), Von Neumann and Morgenstern (1944), and Nash (1950). Figure 3.3 depicts the genealogy of formal conflict analysis models: Game Theory is constituted of a non-quantitative approach and a quantitative procedure. Non-quantitative analyses are based upon an assumption of relative preference information where one object is preferred equally or more than another. A Decision Maker (DM) does not have to know the exact quantity of distinction. Conversely, the quantitative analyses assume cardinal preference information where real numbers are used for modeling preferences (Hipel and Obeidi, 2005).

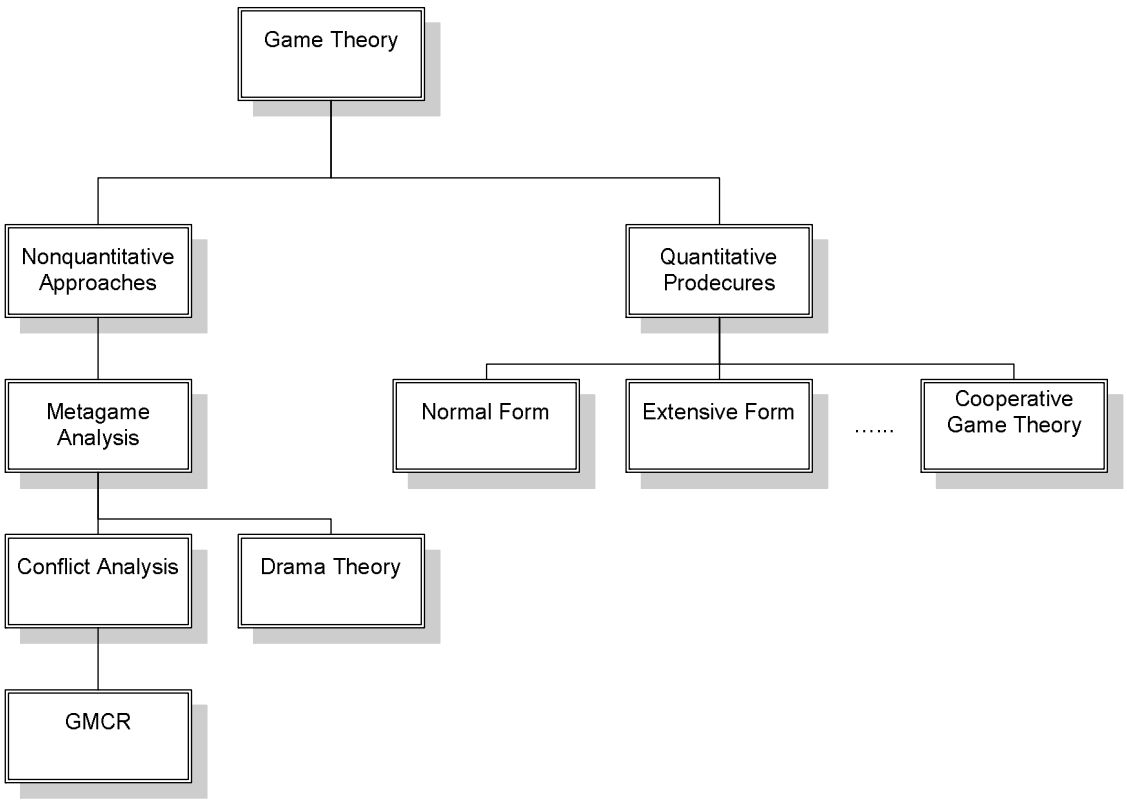

Figure 3.3. Genealogy of Formal Conflict Models (adapted from Hipel and Obeidi, 2005)

Based upon the traditional Game Theory approach, Howard (1971) introduced a non-quantitative model, called metagame analysis. Successively, Fraser and Hipel (1984) developed the Conflict Analysis model (Frasel and Hipel, 1984). The Graph Model for Conflict Resolution is a further improvement of metagame analysis (Fang et al., 1993). Both the metagame analysis and GMCR are generally applied to social conflicts because of their inherent non-quantitative nature (Hipel and Obeidi, 2005). Details of the GMCR are discussed in the next few sections.

3.2. The Graph Model for Conflict Resolution

The Graph Model for Conflict Resolution is a systematic approach that handles complicated strategic decision problems involving two or more DMs with differing preferences (Kilgour et al., 1987; Fang et al., 1993). With this model, interested parties "analyze a conflict and obtain a better understanding about what is currently happening and what could eventually take place" (Fang et al., 1993).

3.2.1. General Procedure

Figure 3.4 depicts the general procedure for practically applying GMCR to a real conflict situation. Within the modeling stage, the complicated conflict is transformed into a mathematical model by defining; the involved DMs, their corresponding actions or options, possible states or alternatives, and preferences reflecting their interests and objectives. Sequentially, the problem is investigated from the individual stabilities to

overall equilibria, and then through, interpretation and sensitivity analyses. Finally, the obtained information is forwarded to DMs, and assists them to make decisions. Similar to the general conflict analysis process, the analysis procedure of GMCR contains feedback, which keeps the analytical model interacting with the actual situations. Additionally, the model also allows DMs, or interested parties, to retrieve a certain analysis stage based upon any insights received from the feedback.

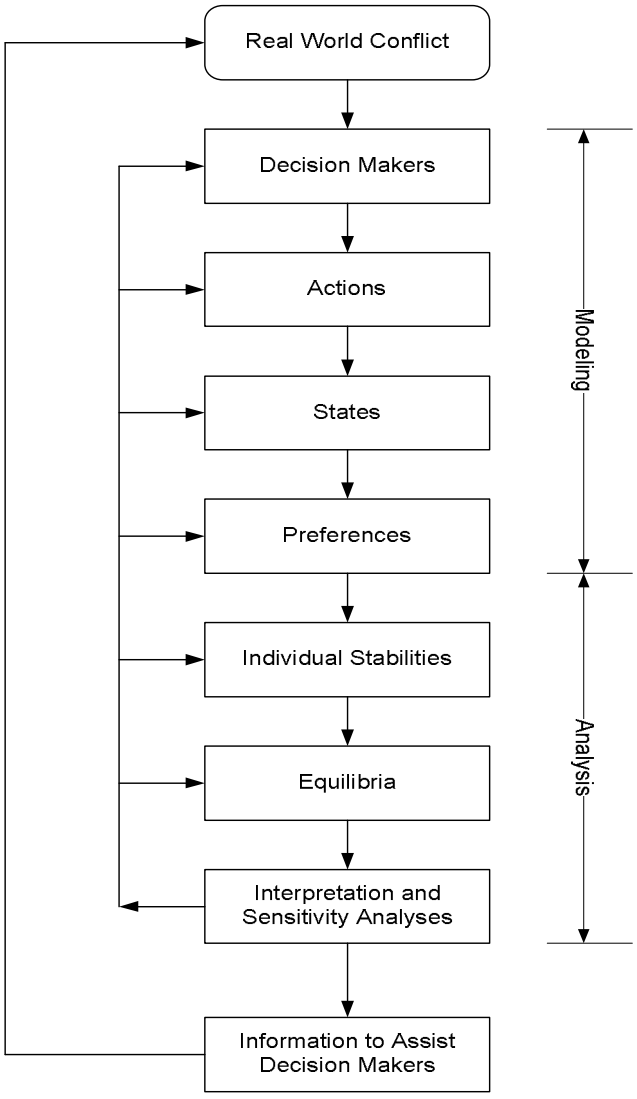

Figure 3.4. Two Stages of GMCR (adapted from Fang et al., 1993)

3.2.2. Modeling

GMCR focuses on strategic level conflict analysis with a structure of four components (Fang et al., 1993; Li et al., 2004a; Kilgour and Hipel, 2005):

1) a set of DMs $N = \{1, 2, ..., n\}$;

2) a set of feasible states $S = \{s_1, s_2, ..., s_m\}$;

3) a set of preference relationships among the states $P = \{P_i, i \in N\}$, where P_i denotes the preferences for DM *i*, which is typically expressed as pair of binary relations, $\{\succ, \sim\}$ on *S*, respectively, representing strict preference and indifference. In other words, $s_1 \succ_i s_2$ denotes that DM *i* prefers s_1 to s_2, and $s_1 \sim_i s_2$ represents that DM *i* is indifferent between s_1 and s_2, where $s_1, s_2 \in S$. More specifically, the operator $\succ_i$ is asymmetric (i.e., $s_1 \succ s_2$ and $s_2 \succ s_1$ cannot be both true); and the operator $\sim_i$ is reflexive and symmetric (i.e., if $s \in S$, then $s \sim_i s$ for any $s \in S$; and if $s_1 \sim_i s_2$, then $s_2 \sim_i s_1$).

4) a set of directed graphs $\{G_i, i \in N\}$, where G_i indicates the possible moves among the states controlled by DM *i*.

In GMCR, a term called Unilateral Movement (UM) is defined as a movement that may only be completed in one-step. If, from a state *s*, a player *i* can move unilaterally to another state s', state s' is considered to be in the reachable list of state *s*. Let $R_i(s)$ denotes player *i*'s reachable list from state *s*, then

$$R_i(s) = \{s' \in S : (s, s') \in A_i\}.$$

Moreover, after introducing preferences, a certain player may only be willing to unilaterally move from a less preferred state to a more preferred one. The list that contains this information is called the Unilateral Improvement (UI) list. In terms of the reachable list, player *i*'s unilateral improvement list from state *s*, denoted by $R_i^+(s)$, can be defined as:

$$R_i^+(s) = \{s' \in R_i(s) : s' \succ_i s\}$$

3.2.3. Solution Concepts

In GMCR, several specific solution concepts, also called stability definitions, are used to define stability. These solution concepts describe DMs' possible behavioral patterns in conflicts. A state is stable for a DM when he/she has no incentive to move away from the state unilaterally. When a state is stable for all DMs under a certain solution concept, it is said to be an equilibrium and represents a potential resolution for this conflict. Six main stability definitions were embodied in GMCR, including: Nash Stability (Nash) (Von Neumann and Morgenstern 1944, 1953; Nash, 1950, 1951), General Metarationality (GMR) (Howard, 1971), Symmetric Metarationality (SMR) (Howard, 1971), Sequential Stability (SEQ) (Fraser and Hipel, 1979, 1984), Limited Move Stability (L_h) (Kilgour, 1985; Kilgour et al., 1987; Zagare, 1984), and Non-Myopic Stability (NM) (Brams and Wittman, 1981; Kilgour, 1984, 1985; Kilgour et al., 1987).

For conflicts with two DMs, denote $N = \{i, j\}$ and two DMs as DM *i* and DM *j*.

Moreover, define $s_1 \succsim s_2$ iff $s_1 \succ s_2$ or $s_1 \sim s_2$.The following solution concepts can be defined (Li et al., 2004a; Hamouda et al., 2004).

Definition 3.1. Let $i \in N$, a state $s \in S$ is *Nash Stable (or individual rational) (R)* for DM *i,* denoted by $s \in S_i^{Nash}$, iff $R_i^+(s) = \varnothing$.

Definition 3.2. Let $i \in N$, a state $s \in S$ is *General Metarational (GMR)* for DM *i*, denoted by $s \in S_i^{GMR}$, iff for every $s_1 \in R_i^+(s)$, there exists at least one $s_2 \in R_j(s_1)$ with $s \succsim_i s_2$.

Definition 3.3. Let $i \in N$, a state $s \in S$ is *Symmetric Metarational (SMR)* for DM *i*, denoted by $s \in S_i^{SMR}$, iff for every $s_1 \in R_i^+(s)$, there exists at least one $s_2 \in R_j(s_1)$, such that $s \succsim_i s_2$ and $s \succsim_i s_3$ for all $s_3 \in R_i(s_2)$.

Definition 3.4. Let $i \in N$, a state $s \in S$ is *Sequential Stable (SEQ)* for DM i, denoted by $s \in S_i^{SEQ}$, iff for every $s_1 \in R_i^+(s)$, there exists $s_2 \in R_j^+(s_1)$ with $s \succsim_i s_2$.

The 2-DM definitions can be extended to general *n*-DM (*n*>2) models with the introduction of the concepts of Unilateral Movements and Unilateral Improvements by a group of DMs.

For conflicts with *n* DMs, let $M \subseteq N (M \neq \varnothing)$ be a subset of all DMs, and $s \in S$. Denote $R_M(s)$ as the set of all states that can be reached through any legal sequence of UMs from state s by some or all DMs in *M*. If $s_1 \in R_M(s)$, let $\Omega_M(s, s_1)$ be the set of all last DMs in legal sequences from *s* to s_1 (Li et al., 2004a; Hamouda et al., 2004).

Definition 3.5. Let $s \in S$ and $M \subseteq N (M \neq \varnothing)$. A UM from state *s* by *M*, a member of $R_M(s) \subseteq S$, is defined inductively by:

(i) if $i \in M$ and $s_1 \in R_i(s)$, then $s_1 \in R_M(s)$ and $i \in \Omega_M(s, s_1)$.

(ii) if $s_1 \in R_M(s)$, $j \in M$ and $s_2 \in R_j(s_1)$, then

(a) if $|\Omega_M(s, s_1)|=1$ and $j \notin \Omega_M(s, s_1)$, then $s_2 \in R_M(s)$ and $j \in \Omega_M(s, s_2)$;

(b) if $|\Omega_M(s, s_1)|>1$, then $s_2 \in R_M(s)$ and $j \in \Omega_M(s, s_2)$.

$R_M(s)$ is constructed by

(i) adding states that are UMs from state *s* by all DMs in *M*, and

(ii) adding states that can be reached by sequences of joint moves by some or all DMs in *M*.

Similarly, the relevant definitions of UIs by a group of DMs can be presented. Let $M \subseteq N(M \neq \varnothing)$ be a subset of all DMs, and $s \in S$. Denote $R_M^+(s)$ as the set of all states that can be reached through any legal sequence of UIs from state *s* by some or all DMs in *M*. If $s_1 \in R_M^+(s)$, let $\Omega_M^+(s, s_1)$ be the set of all last DMs in legal sequences from *s* to s_1 (Li et al., 2004a; Hamouda et al., 2004).

Definition 3.6. Let $s \in S$ and $M \subseteq N(M \neq \varnothing)$. A UI from state *s* by *M*, a member of $R_M^+(s) \subseteq S$, is defined inductively by:

(i) if $i \in M$ and $s_1 \in R_i^+(s)$, then $s_1 \in R_M^+(s)$ and $i \in \Omega_M^+(s, s_1)$.

(ii) if $s_1 \in R_M^+(s)$, $j \in M$ and $s_2 \in R_j^+(s_1)$, then

(a) if $|\Omega_M^+(s, s_1)|=1$ and $j \notin \Omega_M^+(s, s_1)$, then $s_2 \in R_M^+(s)$ and $j \in \Omega_M^+(s, s_2)$;

(b) if $|\Omega_M^+(s, s_1)|>1$, then $s_2 \in R_M^+(s)$ and $j \in \Omega_M^+(s, s_2)$

$R_M^+(s)$ is constructed by:

(i) adding states that are UIs from state *s* by all DMs in *M*, and

(ii) adding states that can be reached by sequences of joint Unileral Improvements by some or all DMs in *M*.

The sets $R_{N-i}(s)$ and $R^{+}_{N-i}(s)$ represent the responses or credible sanctions by DM *i*'s rivals against *i*.

Hence, stability definitions for Nash, GMR, SMR and SEQ can be defined for *n*-DM models.

Definition 3.7. Let $i \in N$, a state $s \in S$ is Nash Stable for DM *i*, denoted by $s \in S_i^{Nash}$,iff $R_i^{+}(s) = \varnothing$

Definition 3.8. Let $i \in N$, a state $s \in S$ is *General Metarational* for DM *i*, denoted by $s \in S_i^{GMR}$,iff for every $s_1 \in R_i^{+}(s)$,there exists at lease one $s_2 \in R_{N-i}(s_1)$,such that $s \succsim_i s_2$.

Definition 3.9. Let $i \in N$, a state $s \in S$ is *Symmetric Metarational* for DM *i*, denoted by $s \in S_i^{SMR}$,iff for every $s_1 \in R_i^{+}(s)$,there exists at lease one $s_2 \in R_{N-i}(s_1)$,such that $s \succsim_i s_2$ and $s \succsim_i s_3$, for all $s_3 \in R_i(s_2)$.

Definition 3.10. Let $i \in N$, a state $s \in S$ is *Sequentially Stable* for DM *i*, denoted by $s \in S_i^{SEQ}$,iff for every $s_1 \in R_i^{+}(s)$,there exists at lease one $s_2 \in R^{+}_{N-i}(s_1)$,such that $s \succsim_i s_2$.

Four important behavioral characteristics are listed in Table 3.1. As an important feature, foresight refers to a DM's capacity of foreseeing possible future moves under a particular stability definition. As shown in Table 3.1, Nash stability has the lowest foresight, while Non-myopic stability has the highest. To obtain Nash, GMR, or SMR, DMs may only need knowledge of their own preferences, while knowledge of all

preferences is required to assess other three stability definitions. The strategic disimporvement in the next column means a DM may move to a less preferred state temporarily in order to reach a more preferred one eventually. The disimporvement by opponents means that other DMs may choose to move to a less preferred state in order to block the focal DM's unilateral improvements. The column of Strategic Risk contains the information of DMs' different attitudes towards risks, which may affect their decisions. More details may be found in Fang et al. (1993, 2003b) and Kilgour and Hipel (2005).

Table 3.1. The Behavioral Characteristics of Solution Concepts

(adapted from Fang et al., 1993)

Solution Concepts	Foresight	Knowledge of Preferences	Disimprovement	Strategic Risk
Nash stability (R)	Low	Own	Never	Ignores risk
General metarationality (GMR)	Medium	Own	By opponents	Avoids risk; Conservative
Symmetric metarationality (SMR)	Medium	Own	By opponents	
Sequential stability (SEQ)	Medium	All	Never	Takes some risks; satisfies
Limited-move stability (L_h)	Variable	All	Strategic	Accepts risk; Strategizes
Non-myopic stability (NM)	High	All	Strategic	

3.2.4. Follow-up Analyses

Sensitivity analysis is one of the most useful procedures in GMCR. Through comparison of the stability resolutions by meaningfully modifying model parameters,

sensitivity analysis provides a tool for users to gain a more comprehensive knowledge of the conflict situation. Corresponding to the particular characteristics of the investigated problem, the types of sensitivity analysis may vary in the following list: preference changes, option modification or expansion, side payments, modification of DMs, human behavior consideration, coalitions, entertainment of other modes to bargaining and negotiation.

As stated by Kilgour et al. (2001), "A coalition is a group of at least two, but not all of the parties, that coordinate its actions in the interests of all the coalition partners – at least in the short term." The investigations of coalitions bring more insights into a normal conflict analysis and make the application more convenient.

Being another interesting topic in GMCR, status quo analysis allows users to comprehend the trend of conflict problems starting from status quo, passing through states based on the DMs' interactions, and finally, reaching the outcomes or equilibria. For details of status quo analysis, please refer to Li et al. (2004b).

Moreover, many other analysis procedures are developed to supplement the basic stability analysis of GMCR, such as hypergame analysis, emotion analysis, attitude analysis, uncertainty, preference eliciting, and so on. These procedures assist GMCR to achieve its goals.

3.3. Modeling Attitudes in GMCR

In the area of social psychology, attitude is defined as "an enduring system of positive or negative evaluations, emotional feeling and pro and con action tendencies,

with respect to a social object" (Krech et al., 1962). The concept of attitudes is classified into three types: positive, negative and neutral (Taylor, 1970). Inohara et al. (2007) introduced the concept of attitude into GMCR by modifying and expanding the original definitions of preferences, special types of moves among states, and related solution concepts. The most important definitions related to attitudes in GMCR are presented as follows (Inohara et al., 2007).

Definition 3.11. (Attitudes): For DMs $i, j \in N$, let $E_i = \{+, 0, -\}^N$ represent the set of attitudes of DM *i*. An element $e_i \in E_i$ is called the attitudes of DM *i*, for which $e_i = (e_{ij})$ is the list of attitudes of DM i towards DM j for each $j \in N$, where $e_{ij} \in \{+, 0, -\}$. The e_{ij} is referred to as the attitude of DM *i* to DM *j* where the values $e_{ij} = +$, $e_{ij} = 0$ and $e_{ij} = -$ indicates that DM *i* has a positive, neutral and negative attitude towards DM *j*, respectively.

Table 3.2 shows how attitude information can be illustrated in the matrix form. The entry at row *i* and column *j* represents the attitude of DM *i* to DM *j*, with a value of $+$, 0 or $-$. When all attitude values are 0, the given model is a so-called "rational" model. When attitudes are taken into account, the given model is "relational".

Table 3.2. Attitudes in Matrix Form

DM	i	J
i	e_{ii}	e_{ij}
j	e_{ji}	e_{jj}

Essentially, DMs' preferences are the elements that are mostly impacted by attitudes. Definitions 3.6 to 3.12 provide the theoretical descriptions of related preference structures.

Definition 3.12. (Devoting preference (DP)): The devoting preference of DM $i \in N$ with respect to DM $j \in N$ is $\succeq_j$, denoted by DP_{ij}, such that for $s,t \in S$, $s\ \mathrm{DP}_{ij}\ t$ if and only if $s \succeq_j t$.

Definition 3.13. (Aggressive preference (AP)): The aggressive preference of DM $i \in N$ with respect to DM $j \in N$ is $NE\left(\succ_j\right)$, denoted by AP_{ij}, where $NE\left(\succ_j\right)$ is defined as follows: for $s,t \in S$, $s\ NE\left(\succ_j\right)\ t$ if and only if $s \succ_j t$ is not true. That is, for $s,t \in S$, $s\ \mathrm{AP}_{ij}\ t$ if and only if $s\ NE\left(\succ_j\right)\ t$ (iff $t \succeq_j s$ under completeness of $\succeq_j$).

Definition 3.14. (Relational preference) The relational preference $\mathrm{RP}\left(e_{ij}\right)$ of DM $i \in N$ with respect to DM $j \in N$ is defined as follows:

$$\mathrm{RP}\left(e_{ij}\right) = \begin{cases} \mathrm{DP}_{ij} & \text{if} \quad e_{ij} = + \\ \mathrm{AP}_{ij} & \text{if} \quad e_{ij} = - \\ \mathrm{I}_{ij} & \text{if} \quad e_{ij} = 0 \end{cases},$$

where I_{ij} denotes that DM *i* is indifferent with respect to *j*'s preference and, hence, $s\ \mathrm{I}_{ij}\ t$ means that DM *i*'s preference between states *s* and *t* is not influenced by DM *j*'s preference.

Definition 3.15. (Total relational preference (TRP)) The total relational preference of DM $i \in N$ at e is defined as the ordering $\mathrm{TRP}\left(e\right)_i$ such that for $s,t \in S$,

s $\mathrm{TRP}(\mathrm{e})_i$ t if and only if s $\mathrm{RP}(e_{ij})$ t for all $j \in N$.

Definition 3.16. (Total relational reply (TRR)) The total relational reply list of DM $i \in N$ at e for state $s \in S$ is defined as the set $\{t \in R_i(s) \cup \{s\} \mid t \ \mathrm{TRP}(e)_i \ s\}$ $\subset R_i(s) \cup \{s\}$, denoted by $\mathrm{TRR}(e)_i(s)$.

Definition 3.17. (Total relational reply list of a coalition) The total relational reply list of coalition $H \subset N$ at e for state $s \in S$ is defined inductively as the set $\mathrm{TRR}(e)_H(s)$ that satisfies the next two conditions: 1) if $i \in H$ and $t \in \mathrm{TRR}(e)_i(s)$, then $t \in \mathrm{TRR}(e)_H(s)$, and 2) if $i \in H$ and $t \in \mathrm{TRR}(e)_H(s)$ and $u \in \mathrm{TRR}(e)_i(s)$, then $u \in \mathrm{TRR}(e)_H(s)$.

Definition 3.18. (Relational less preferred or equally preferred states) The symbol $R\phi^{=}(e)_i(s)$ is an analogue of $\phi^{=}(s) = \{x \in S \mid s \succeq_i x\}$. Hence, $R\phi^{=}(e)_i(s)$ is the set of all states which are "relational less or equally preferred" to *s* by DM *i* (under attitude *e*).

Similar to the regular graph model analysis, after applying attitude information to the DMs' preference structures, the stability analyses of the given model are ready to be carried out. Corresponding to the solution concepts explained in last section, the revised stability definitions, which are called "relational" solution concepts, are furnished as follows.

Definition 3.19. (Relational Nash stability) For $i \in N$, state $s \in S$ is relational Nash stable at e for DM *i*, denoted by $s \in S_i^{RNash(e)}$, if and only if $\mathrm{TRR}(e)_i(s) = \{s\}$.

Definition 3.20. (Relational general metarationality (RGMR)) For $i \in N$, state $s \in S$ is relational general metarationality at e for DM *i*, denoted by $s \in S_i^{RGMR(e)}$, if and

only if for all $x \in \mathrm{TRR}(e)_i(s) \setminus \{s\}$, $R_{N\setminus\{i\}}(x) \cap R\phi^{=}(e)_i(s) \neq \phi$.

Definition 3.21. (Relational symmetric metarationality (RSMR)) For $i \in N$, state $s \in S$ is relational symmetric metarationality at e for DM *i*, denoted by $s \in S_i^{RSMR(e)}$, if and only if for all $x \in \mathrm{TRR}(e)_i(s) \setminus \{s\}$, there exists $y \in R_{N\setminus\{i\}}(x) \cap R\phi^{=}(e)_i(s)$ such that $z \in R\phi^{=}(e)_i(s)$ for all $z \in R_i(y)$.

Definition 3.22. (Relational sequential stability (RSEQ)) For $i \in N$, state $s \in S$ is relational sequential stability at e for DM *i*, denoted by $s \in S_i^{RSEQ(e)}$, if and only if for all $x \in \mathrm{TRR}(e)_i(s) \setminus \{s\}$, $\mathrm{TRR}(e)_{N\setminus\{i\}}(x) \cap R\phi^{=}(e)_i(s) \neq \phi$.

Detailed explanations of the definitions regarding applying attitudes to GMCR can be found in Inohara (2007). In Chapter 5, a real-world conflict, within the dimension of international toxic waste disposal, illustrates how to implement this specific analysis in practice.

3.4. Decision Support System GMCR II

Decision support system (DSS) aims to computerize a specific methodology or algorithm, and therefore, facilitate users with a much more convenient and reliable way to implement the given methodology. GMCR II is the second version of a DSS that is based on the methodology of GMCR. Because of its friendly user interface and comprehensive analysis engine, GMCR II provides a practical and efficient way to assist users in all phases of modeling, analyzing, and interpreting strategic conflicts.

Consequently, users may not only be someone who is specialized in conflict analysis or computer systems, but also be anybody in any discipline that deals with a particular dispute (Fang et al., 2003a, 2003b).

This DSS can be beneficially applied to three main situations listed as follows (Fang et al., 2003b; Kilgour and Hipel, 2005).

1) *Analysis and simulation tool for conflict participants:* GMCR II can be used in simulation or role-playing exercises that aim to achieve a better understanding or prediction of real world conflicts.

2) *Analysis and communication tool for mediators:* GMCR II can be used by mediators to reconcile opposite situations, creat a more harmonious atmosphere in which to carry out negotiations, and assist in conducting and settling the disputes more effectively.

3) *Analysis tool for a third party or a regulator:* GMCR II can be used by other interested parties, such as representatives of third party or a regulator, as a helpful mechanism to understand the conflict and perhaps seek fact-binding or legal-binding rules.

The structure of GMCR II is illustrated in Figure 3.5. Through the user interface, Modeling Subsystems build up the graph model with all related information, such as the DMs, their corresponding options, infeasibility information, and last but not least, preferences. Then, the modeling information enters the Analysis Engine for further investigation. The important analysis procedures, as mentioned in the last section, such as stability analysis, coalition analysis, and status quo analysis, are carried out in this subsystem. Finally, the analysis results or resolutions, for instance, individual stabilities,

overall equilibria, and coalition stabilities, are constructed in the Output Subsystem and delivered to the users through the Graphical User Interface. For a special user who has particular requirements, these requests may be directed additionally from the user interface to the Analysis Engine.

Within each subsystem, GMCR II has its specific design to complete the functions. For example, preference information is one of the most critical and intractable issues. In GMCR II, this job could be fulfilled by three technologies, option weighting, option prioritizing, and direct ranking. Each technology is employed to deal with a certain situation, and the direct ranking method can be combined with one of other two to fine tune the preferences. Details about GMCR II may be found in Fang et al. (2003a, 2003b).

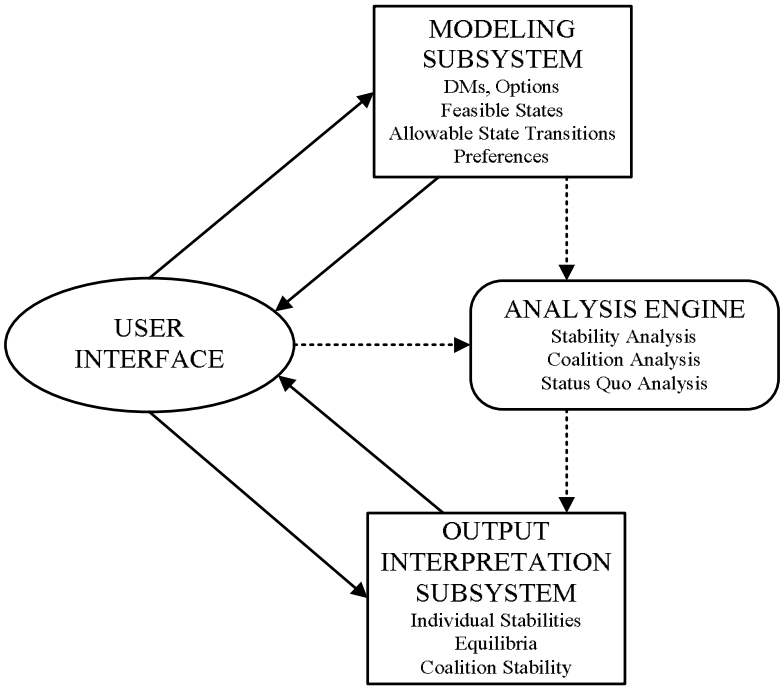

Figure 3.5. GMCR II Structure (Fang et al., 2003a; Kilgour and Hipel, 2005).

3.5. Summary

This chapter started with basic concepts of general conflict analysis and a brief history of Game Theory. The introduction focused on the methodology of the Graph Model for Conflict Resolution. The detailed explanation of four key components and stability definitions for 2-DM and *n*-DM (n>2) models demonstrated the characteristics and strength of GMCR. The extended contents of sensitivity analysis and attitude analysis motivate further consideration.

Chapter 4 Generic Multi-Stage Graph Model Analysis for International Toxic Waste Disposal Dispute

A generic multi-stage graph model is developed to analyze the international toxic waste disposal dispute. This multilateral dispute involves nations with different cultures and is related to areas of the environment, legal issues and economical conditions. The Generic Multi-Stage Graph Model organizes the analytic process by dividing the dispute into two stages: the dumping prevention stage and the conflict resolution stage. Each stage may contain more than one model in regards to the actual situation. It follows, therefore, that a complex problem can be transformed into a combination of several simpler modules. The methodology of the Graph Model for Conflict Resolution (GMCR) is applied to each module in order to analyze feasible resolutions through the implementation of the Decision Support System GMCR II.

4.1. Decision Makers

As stated in Chapter 2, there are four parties involved in the international toxic waste disposal conflicts: the receiving country, the toxic waste trader, the United Nations, and

Non-Governmental Organizations. A detailed discussion of each DM is presented in this section.

4.1.1. The Receiving Countries (RC)

Generally, only poor countries, or developing countries, are potential receiving countries due to the pressure of the financial difficulties they face. These countries have usually undergone colonization, have war in their history, or are restricted by natural conditions, such as destitute natural resources and/or lean soil. Most of them have not experienced industrial revolutions. These countries desire development to improve their economies. In order to maximize their revenue or gain further financial aid, poor countries have to concede to the pressures of international business. "Trash for Food" is a manifestation of their concessions (Puckett, 1997).

Furthermore, the sluggish, even stagnant economies cannot provide financial support to the operations of these countries. The governments of these countries function in a disorderly and improper manner, because their capabilities for policy-making and legislation are often lacking. The problem inevitability emerges in the environmental legislation and the relevant management systems (Asante-Duah and Sam, 1995):

- Lacking complete environmental legal systems;
- Lacking authorities to control and monitor the environmental issues;
- Lacking disposal technologies to minimize the damage of hazardous wastes;
- Lacking public attention and risk perception on environmental issues.

All of these existing problems in developing countries result in their being targeted as

international hazardous wastes dumping grounds.

Many developing countries possess excellent natural environments and abundant natural sources, such as the tropical rainforest of Africa and of the Amazon Rainforest in South America. In past decades, these undeveloped areas were in a primarily undisturbed natural condition because of the low level of industrialization. However, as development progressed in these countries, especially during recent energy and natural resources crises, the resulting overexploitation has severely impacted environment in these areas. For example, Economist.com (2006) stated that "tropical forest is vanishing at a rate of 5% a decade, destroying habitats and releasing 3 billion tonnes of carbon dioxide a year, a fifth of global greenhouse emissions". Due to the shortage of knowledge in environmental protection technologies, these countries cannot efficiently prevent environmental damage, and as a result experience a higher risk of undergoing the tragic results.

4.1.2. The Toxic Waste Trader (WT)

Since toxic waste trade began in the 1970s, numerous hazardous wastes have been shipped from the USA, EU and Australia to poor countries in Africa, Asia, and South America (Clapp, 2001). These highly developed nations are equipped with the most advanced manufacturing facilities in the world, which are able to produce a large amount of products and hazardous wastes. The production of huge quantities of hazardous wastes has essentially created a business opportunity for toxic waste traders (Asante-Duah and Nagy, 1998).

Seemingly, the case of toxic waste trades relates to the commercial activities of toxic waste traders. Their operations include collecting, transporting, exporting, and importing toxic wastes. These companies organize toxic waste trade and profit from this activity. However, toxic waste traders only have a relatively share of the global waste trade market. The biggest beneficiaries behind the scenes are those large manufacturing companies or their holding companies. More precisely, these large corporations usually have strong connections with the governments of their nations, due to their solid financial strength. As government supporters, their interests are consistent with their governments, and their influence may influence the policy making of countries. Therefore, it is understandable that many advanced countries are unwilling to ratify, or even undermine the Basel Convention and Ban Amendment.

Furthermore, due to the tremendous number of cases of dumping toxic wastes, it is virtually impossible to collect data to quantify the activity of waste traders. Some traders may be based in the sending countries that have ratified the Convention and Ban Amendment, while others may not. Traders often adopt some tricks to evade their responsibilities. For instance, the fact that most traders are multinational corporations, increases the difficulty of carrying out investigations. Moreover, although these nations have ratified the Convention and Ban Amendment and could affect traders' behaviors, there are still numerous hazardous wastes being transported across their borders. Because of the forgoing and other reasons, the countries of origin of waste trader, are not consider as separate DM in the hazardous waste conflict model developed in this thesis. Nevertheless, if for a specific dispute, a given country did exhibit decisive action in stopping harmful hazardous waste trade, it could be entertained as a separate DM in the

conflict model.

4.1.3. The United Nations (UN)

The largest of international organizations, the United Nations (UN), was created in 1945. Its purposes are to "maintain international peace and security; to develop friendly relations among nations; to cooperate in solving international economic, social, cultural and humanitarian problems and in promoting respect for human rights and fundamental freedoms; and to be a centre for harmonizing the actions of nations in attaining these ends" (United Nations, 1945).

4.1.3.1. UN system

The establishment of the UN system seeks to exert its function, in order to reach the UN's aims. The UN system consists of six principal organs: *the General Assembly, the Security Council, the Economic and Social Council (ECOSOC), the Secretariat, the International Court of Justice (ICJ),* and *the Trusteeship Council*. The UN also includes 15 agencies and several programs and bodies. Figure 4.1 shows the organization of the UN system (News and Media Division, United Nations Department of Public Information, 2004).

4.1.3.2. International Law

The UN system has contributed to world peace and development since its foundation. Among all of the UN's achievements, one of the most distinguished is the construction of an international law system consisting of conventions, treaties and standards. The

international law provides a framework for regulating multilateral relationships and legally-binding settlements for international disputes.

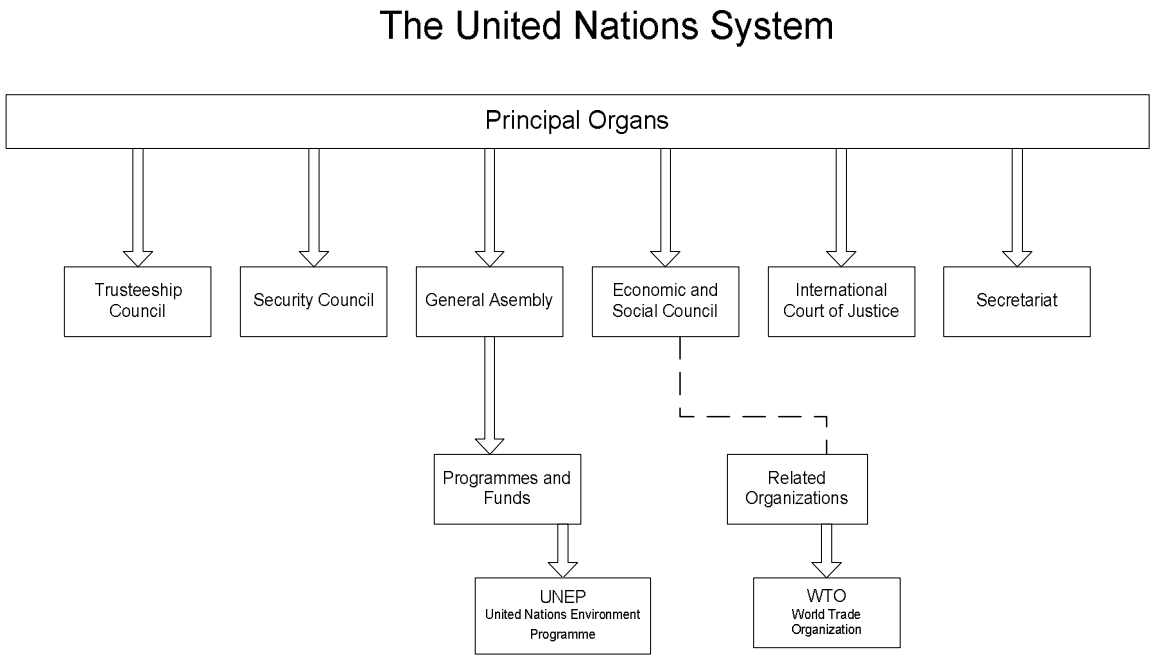

Figure 4.1. The United Nations System

The International Court of Justice (ICJ) is the principal judicial organ of the UN system, established by the UN Charter, San Francisco (United States), in 1945, and was subsequently located in 1946 in the Peace Palace, The Hague (The Netherlands).

The Court, which is composed of 15 judges, has a dual role: settling legal disputes in accordance with international law, and acting as an advisor on legal matters related to international disputes or authorized by organs and specialized agencies of the UN system (News and Media Division, United Nations Department of Public Information, 2004).

4.1.3.3. The Basel Convention as International Environmental Law

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in Basel, Switzerland in March 1989. It entered into force in May 1992. The Convention aims to minimize the generation of hazardous wastes in the world, and to dispose of the hazardous wastes locally and reduce their movements. The Basel Convention constructs legal instruments to control transboundary movements of hazardous wastes and other wastes.

Of first importance to the convention parties is the consideration of illegal transboundary movements of hazardous wastes as being criminal in nature. Further, the parties are obligated to prohibit the import or export of hazardous wastes.

Secondly, The Ban Amendment calls for a full ban exports of hazardous wastes (for any purpose) from countries which is purposed in the new annex to the Basel Convention (Annex VII - Parties that are members of the EU, OECD, Liechtenstein) to any other Party to the Convention. In order to enter into force, the passage of the Ban amendment must obtain ratifications from three fourths of the Parties who accepted it.

Thirdly, the definition and classification system of the convention enhances its implementation in controlling movement of wastes. The convention requires each party to establish a management system to monitor movement of wastes and to minimize the generation of hazardous wastes.

Fourthly, the Conference of the Parties (COP) is the primary organ of the Basel Convention and is composed of all convention parties who have ratified and acceded to it. The meeting of COP, generally held at least once every two years, adopts decisions and develops policies related to the Basel Convention implementation, and to legal and

technical matters.

Moreover, developing countries have signed a series of regional conventions and agreements in preventing traffic of illegal wastes. These conventions have become supplementary to the Basel Convention. Some examples are listed in Table 4.1. Additionally, many countries have enacted unilateral hazardous waste import bans. Colombia, for example, has a full waste import ban written into its national constitution. Many other countries have established legal bans or policies as a result of the regional commitments cited in Table 4.1. For a detailed discussion and original references, please refer to Puckett (1997).

4.1.3.4. The UN's Role in the Conflict

Generally, International Environmental Law recognizes the following mechanisms to settle the environmental dispute (Secretariat of the Basel Convention, 1989):

1) Negotiation, Mediation and Conciliation - A peaceful procedure where, with the agreement of the disputants, a mediator or conciliator is appointed to conduct fact-finding procedures and seek solutions for a settlement. The recommendation is not binding on the parties.

2) Arbitration - A method of legally binding settlement of disputes by the International Court of Justice or Arbitration under the Basel Convention.

In the UN system, UNEP fulfills an important role, which "is helping to develop the institutional and legal infrastructure to safeguard the global environment. Many international environmental agreements have been established with UNEP's assistance." UNEP has achieved effective cooperation and strong links with many partners: other

organs of the UN, international organizations, national governments, NGOs, business, industry, the media and civil society. UNEP may also work as a mediator or conciliator in the dispute related to the environmental convention due to its wide-ranging influence and function (United Nations Environment Programme, 2004).

Table 4.1. Regional Conventions

Conventions	Dates	Member states	Descriptions
The Lomé IV Convention	Dec. 1989	African, Caribbean and Pacific (ACP) States	Prohibits the European Union (EU) from exporting nuclear or hazardous wastes to the ACP states, while the ACP countries agreed to prohibit such waste imports from any country.
The Bamako Convention	Jan. 1991	member states of the Organization of African Unity	Bans all forms of hazardous and nuclear waste imports to the African continent; forbids import of products that have been banned for use in the country of manufacture.
The Central American Agreement on Hazardous Waste	Dec. 1992	six Central American nations	Bans all imports of hazardous and radioactive wastes and of toxic substances not permitted in the country of manufacture.
Association of South East Asian Nations (ASEAN)	Sept. 1993	ASEAN	Prohibits the import of toxic wastes into the region of South-East Asia. So far this initiative has yet to bear fruit, leaving this region vulnerable.
The Waigani Convention	Sept.16 1995	the South Pacific Forum States	Prohibits each Pacific Island developing Party from importing hazardous and radioactive wastes from outside of the Convention area. Australia and New Zealand are prohibited from exporting hazardous or radioactive wastes to all other South Pacific Forum Island countries.
The Barcelona Convention Waste Trade Protocol	Oct.1 1996	The Parties to this Mediterranean regional seas	Prohibits the export of hazardous and radioactive wastes to non-OECD countries and for those Parties that are not members of the European Community are prohibited from importing hazardous and radioactive wastes.

4.1.4. Non-Governmental Organizations (NGOs)

A Non-Governmental Organization is a legal organization, which is independent from the control of any government. The history of NGOs dates back to at least the mid-nineteenth century, and was important in the establishment of the UN. As globalization impels intergovernmental action, NGOs are able to flourish in this situation. (Davies, 2006) There are numerous NGOs in the world, which vary in their purposes and structures. Some of them may operate for their own benefit or they may associate with a political party (Willetts, 2002). In this thesis, an NGO is defined as an Environmental Group with a narrow focus on environmental protection, is not-for-profit in nature, such as the NGO Greenpeace.

Although NGOs are independent from any government, their goals reflect the wishes of the people and they have important influences on many international issues. NGOs cooperate with the UN and interact with governments to pursue their goals related to the environmental prevention. Due to their efforts, NGOs obtain a wide base of support and strong connections to developing countries. Furthermore, NGOs also maintain a healthy relationship with the media. The campaign that NGOs launched in 1989 was instrumental in the creation of the Basel Convention. In waste disposal conflicts, NGOs can call for public attention to the dumping scandal, and conduct a campaign to press the involved parties to settle their disputes.

4.2. Modeling and Analysis

A real world conflict is a dynamic phenomenon. The first step in analyzing a conflict is to select the point of time (Fraser and Hipel, 1984). When performing the Multi-Stage Graph Model Analysis, the international toxic waste disposal dispute can be generically divided into two stages: stage I: Dumping Prevention Stage (before a dumping takes place) and stage II: Dispute Resolution Stage (after a dumping occurs). The two stages of the international toxic waste dispute are illustrated in the Figure 4.2.

This disposal dispute reflects the essentials of the conflict between global economic development and environmental protection. The Multi-Stage Graph Model Analysis applied to this dynamic conflict, focuses on analyzing uncertain situations and observing the evolution of the conflict from a strategic viewpoint. For the purpose of conflict analysis, this model simplifies the complicated situation. Based upon this consideration, Stage I initializes the conflict with three DMs: Receiving Country, Waste Trader and United Nations. By comparing this with Stage I, Stage 2 involves one more DM, Non-Governmental Organizations, in which the analysis emphasizes on their effect on the evolution of the conflict. As discussed in the section 4.2.1.2, toxic waste traders and nations that are based in, are all beneficiaries of the global waste trade. The only difference is the ratio of how they share profits. A similar example is the tobacco industry. Smoking has been proven to be harmful to human health. In particular, the chronic Nicotine Poisoning may increase the risk of cancer occurring and cause abortions in pregnant women. However, there is not a national ban on the production of tobacco anywhere the world.

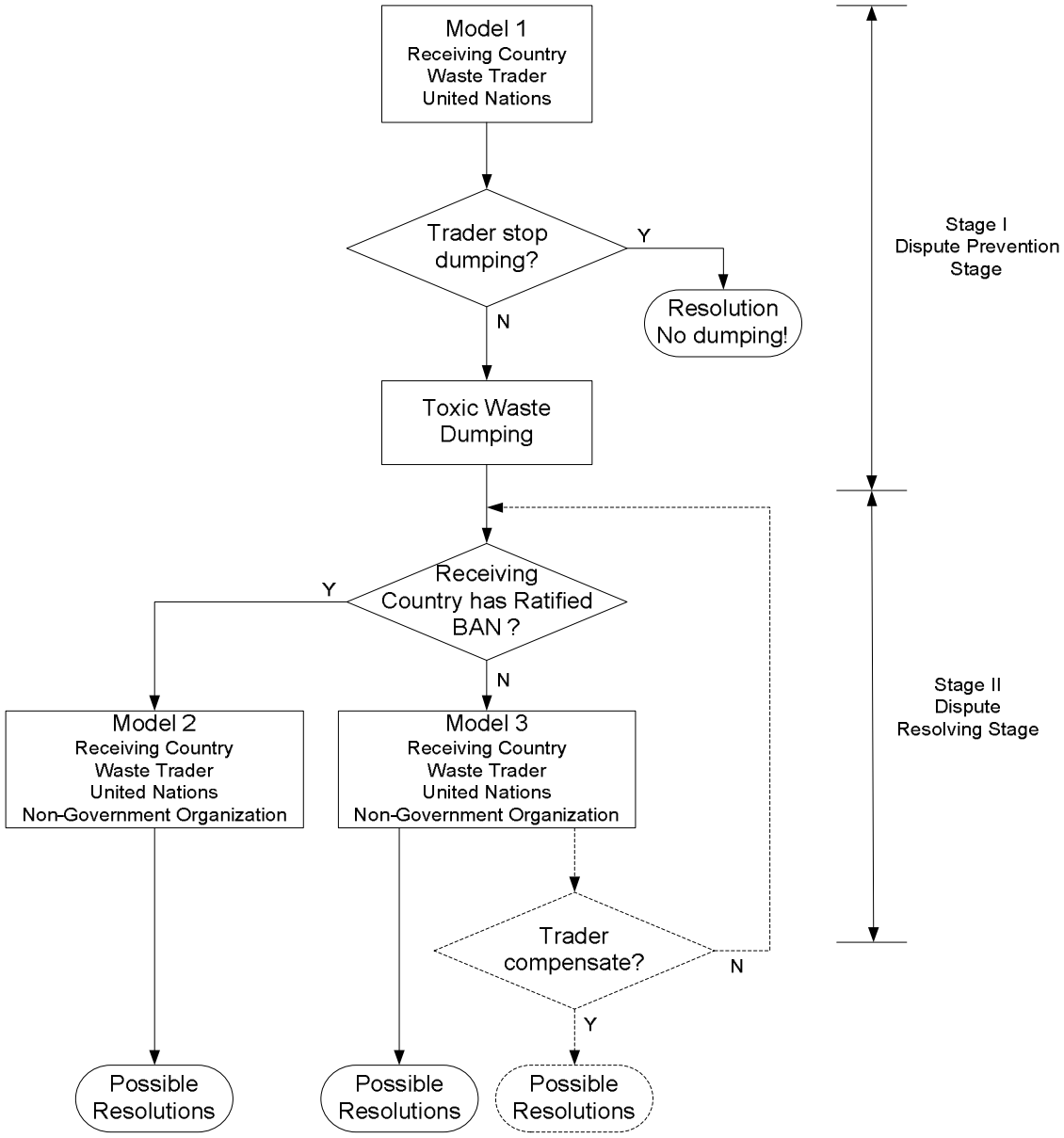

Figure 4.2. Flowchart of the Multi-Stage Analysis for the Toxic Waste Disposal Dispute

4.3. Stage I - Dispute Prevention

In this stage, although waste disposal has not yet occurred, there always remains a possibility of illegal waste traffic. There are three DMs involved in the conflict of the Dumping Prevention Stage: Receiving Country, Waste Trader and United Nations. The poor countries might take a risk in receiving waste for financial benefit. With increasing public consciousness of environmental protection, those poor counties might only accept wastes conditionally. They may require proper treatment of toxic wastes or cleanup offer with any accident of leakage, or they may just ban them completely. Due to the essential need for the pursuing of profits, the toxic waste trader always attempts to continue waste dumping. As the originator and supervisor of international environmental law, the UN cooperates with nations and diverse organizations to control international toxic waste disposal, thus, minimizing its negative impact on the environment. At a chosen time point, the available options for each DM are listed in Tables 4.2.

Table 4.2. Model 1 in Stage I – DMs and Options

DMs	Options
Receiving Country (RC)	1. Import wastes: Accept any potential toxic wastes. 2. Require treatment: Accept proper disposal or require cleanup. 3. Refuse and ratify: Refuse potential toxic wastes and ratify the Convention.
Waste Trader (WT)	4. Dispose wastes: Continue waste dumping. 5. Export and treat: Export and agree to clean up. 6. Stop: Stop all dumping.
United Nations (UN)	7. Press WT: Bring pressure on WT to stop waste dumping. 8. Encourage RC: Encourage RC to refuse wastes and ratify the Convention

For each of the options, DMs may choose to implement it or not. Thus, mathematically, a total of 8 options would represent $2^8 = 256$ possible combinations. Nevertheless, many of them are impossible in reality. For example, the Receiving Country must choose one and only one option, as does the Waste Trader. After considering these circumstances, GMCR II automatically generates a list of 36 feasible states for this model, as shown in Table 4.3.

Figure 4.3 illustrates the procedure of specifying infeasibilities in GMCR II. Two categories of infeasible states are removed: 1) "mutually exclusive" options, which removes the states that contain mutually exclusive options. For these DMs: Receiving Country and Waste Trader, their options are mutually exclusive. 2) "at least one" option, which is used to specify that, for the set of options, at least one option must be selected. In this conflict, Receiving Country must choose at least one from its options, and Waste Trader also must choose at least one from its options.

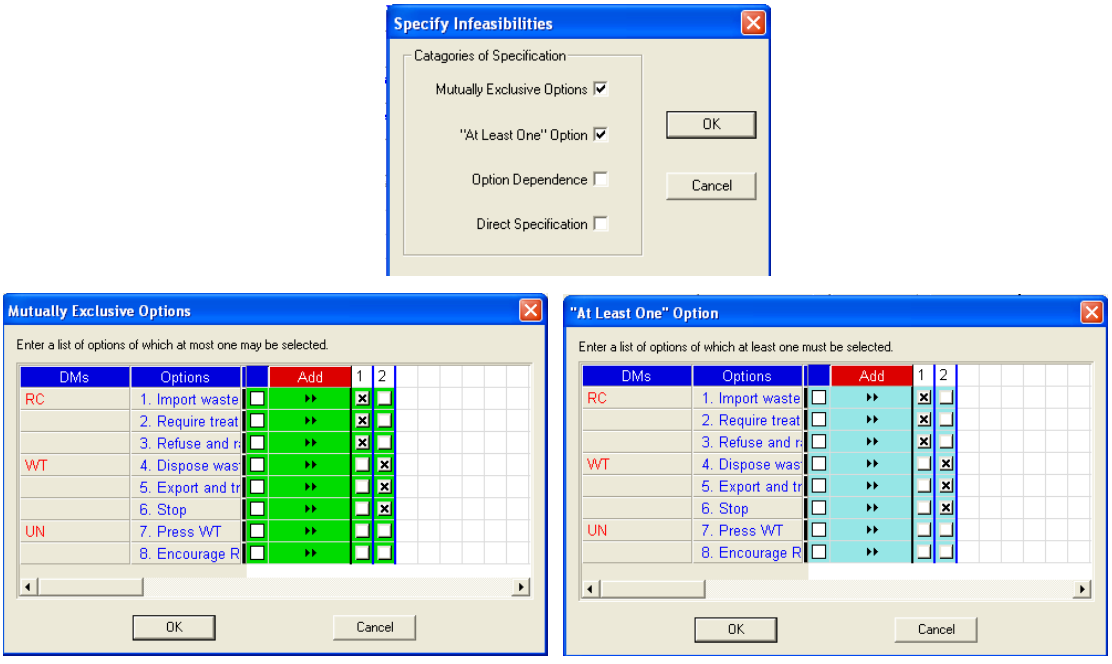

Figure 4.3. Model in Stage I – Remove Infeasible States Using GMCR II

Table 4.3. Feasible States of Model 1 in Stage I

State-→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Receiving Country																		
1. Import wastes	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N
2.Require treatment	N	Y	N	N	Y	N	N	Y	N	N	Y	Y	N	Y	N	N	Y	N
3.Refuse and ratify	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y
Waste Trader																		
4.Dispose wastes	Y	Y	Y	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N
5.Export and treat	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N
6.Stop	N	N	N	N	N	N	Y	Y	Y	N	N	Y	N	N	N	Y	Y	Y
United Nations																		
7.Press WT	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
8.Encourage RC	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

State→	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Receiving Country																		
1. Import wastes	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N
2.Require treatment	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N
3.Refuse and ratify	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y
Waste Trader																		
4.Dispose wastes	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N
5.Export and treat	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N
6.Stop	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y
United Nations																		
7.Press WT	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
8.Encourage RC	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 4.4 depicts the relative preference information for this model. As shown, the numbers from top down represent the corresponding options in the order of most preferred to least preferred. For instance, from the Receiving Country's point of view (column of RC), "-4" denotes that the Receiving Country most prefers that Waste Trader stop dumping; "2" denotes that Receiving Country accepts conditional dumping; "3 IF 8"

represents that the Receiving Country would refuse dumping and ratify the convention if UN encourages it; "7 IF 4" represents that the UN would press the Waste Trader to stop if the Waste Trader continued dumping. Similarly, the preferences of the Waste Trader and the UN are denoted by those numbers in the corresponding columns.

Table 4.4. Model 1 in Stage I – Preference Statements for Option Prioritization

DMs	Receiving Country (RC)	Waste Trader (WT)	United Nations (UN)
Preference Statements	-4	1	6
	2	2	3
	3 IF 8	-7	8
	7 IF 4	-3	7
		-6	5

After the model initialization, the conflict analysis can be carried out by using the associated Decision Dupport System GMCR II. As introduced in Chapter 3, GMCR II performs equilibria analysis effectively with its friendly user interface and powerful analysis engine. Figure 4.4 is the screen shot of equilibria dialog in GMCR II, which illustrates the two possible resolutions' strong stabilities. R, GMR, SMR,SEQ,NM,and L(2) in the lower rows correspondingly represent Nash Stability, General Metarationality, Symmetric Metarationality, Sequential Stability with a horizon of two, Non-Myopic Stability and Limited Move Stability, which have been introduced in Chapter 3. The tick in the column of each state indicates that the state is an equilibrium under the corresponding solution concept in that row. Undoubtedly, states 29 and 32 are equilibria under all listed solution concepts.

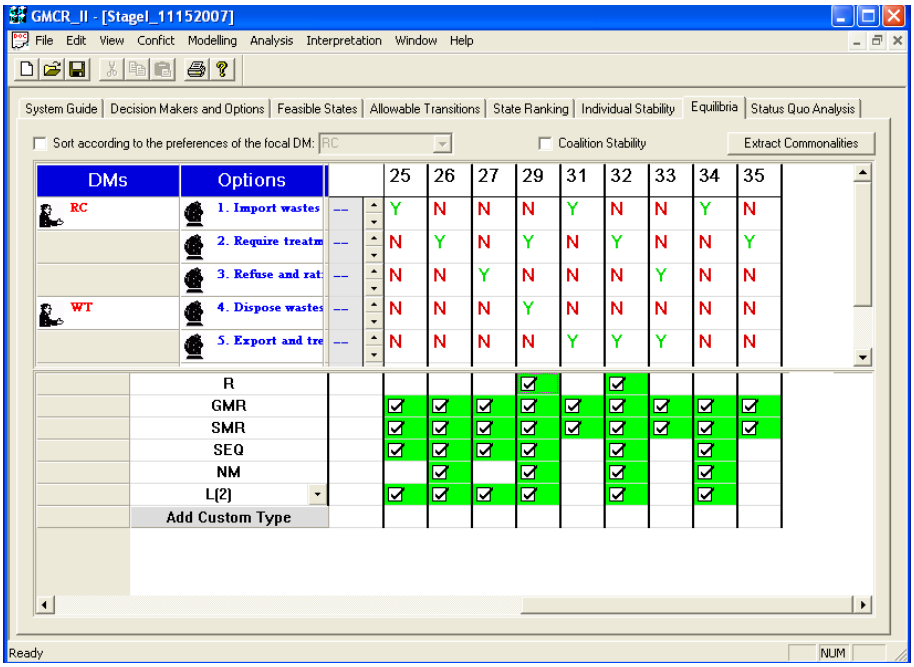

Figure 4.4. Model in Stage I – Equilibria in GMCR II

Table 4.5. Model 1 in Stage I – Summary of Equilibria

DMs and Options	29	32
Receiving Country		
1. Import wastes	N	N
2. Require treatment	Y	Y
3. Refuse and ratify	N	N
Waste Trader		
4. Dispose wastes	Y	N
5. Export and treat	N	Y
6. Stop	N	N
United Nations		
7. Press WT	Y	Y
8. Encourage RC	Y	Y

Table 4.5 summarizes the outcome of two strong stable possible resolutions, which are stable under all solution concepts. In these two possible resolutions, the Receiving Country will accept the toxic dumping conditionally, and hold the Waste Trader for the

proper treatment or cleanup for accidental leakage. The Waste Trader may continue to dump illegally or agree to dispose toxic wastes conditionally. As usual, the UN will press the Waste Trader to stop illegally dumping and call for ratification by the Receiving Country. The results of the prevention stage analyses indicate the possibility of the dispute arising. Once the dumping occurs, the disposal conflict analysis needs to move to the next stage as shown in Figure 4.2.: Flowchart of the Multi-Stage Analysis.

4.4. Stage II - Dispute Resolution

As shown in Figure 4.2, in this stage**,** the dispute has already occurred. The conflict analyses are classified into two models base on the Receiving Country's status of ratification of the Basel Ban Amendment.

4.4.1. Model 2: Receiving Country has Ratified the Basel Ban Amendment

The disposal dispute is under the jurisdiction of the Basel Convention and its Amendments due to the Receiving Country having ratified the Basel Convention. The involved DMs and corresponding options are depicted in Table 4.6.

For each DM, one and only one option can be chosen. Furthermore, in addition to the two categories of infeasibilities, one more technique, option dependence, is employed in this model. This technique can be used to specify two patterns, one of which can occur

only when the other one is satisfied. Specifically, in this case, the UN can only conduct arbitration when the Receiving Country files a claim and the Waste Trader accepts the arbitration. Thus, only 10 states are feasible. The procedure of removing infeasible states are shown in Figure 4.5, and the obtained 10 feasible states are listed in Table 4.7.

Table 4.6. Model 2 in Stage II – DMs and Options

DMs	Options
Receiving Country (RC)	1. Demand compensation: Insist that the trader provide compensation, including cleaning up and paying penalties 2. File claim: Submit the dispute to the UN.
Waste Trader (WT)	3. Accept UN's offer: Accept arbitration or conciliation. 4. Compensate: Agree to compensate RC.
United Nations (UN)	5. Conciliate: Conduct conciliation talks between RC and WT. 6. Arbitrate: conduct arbitration between RC and WT.
Non-Government Organizations (NGOs)	7. Campaign: Influence public to put pressure on WT and press it to stop dumping.

Table 4.7. Feasible States of Model 2 in Stage II

	1	2	3	4	5	6	7	8	9	10
Receiving Country										
1. Demand compensation	Y	N	Y	N	N	Y	N	Y	N	N
2. File claim	N	Y	N	Y	Y	N	Y	N	Y	Y
Waste Trader										
3. Accept UN's offer	Y	Y	N	N	Y	Y	Y	N	N	Y
4. Compensate	N	N	Y	Y	N	N	N	Y	Y	N
United Nations										
5. Conciliate	Y	Y	Y	Y	N	Y	Y	Y	Y	N
6. Arbitrate										
Non-Governmental Organizations	N	N	N	N	Y	N	N	N	N	Y
7. Campaign	N	N	N	N	N	Y	Y	Y	Y	Y

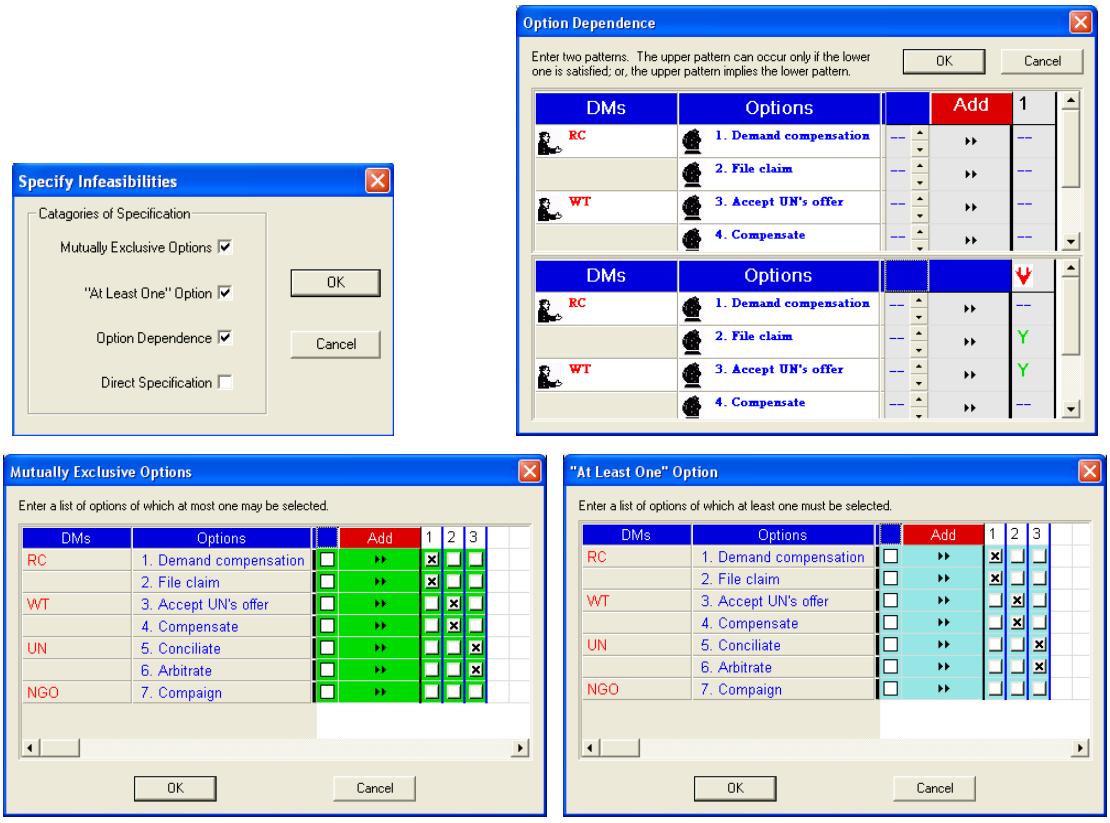

Figure 4.5. Model 2 in Stage II – Remove Infeasible States using GMCR II

Table 4.8 provides the preference information of this model. The details are explained as follows. The Receiving Country will demand compensation for the damage of the disposal according to the convention, or, submit a conciliation or arbitration request to the UN if the Waste Trader refuses to provide compensation. The Waste Trader prefers the UN not to arbitrate, and the Receiving Country not to file a claim. The Waste Trader also tries to avoid compensation. The UN prefers that the Waste Trader to agree to compensate and accept UN's conciliation or arbitration if the Receiving Country files a claim. The UN also likes to see public attention and corresponding pressure on the Waste Trader.

Table 4.8. Model 2 – Preference Statements for Option Prioritization

Decision Makers	Receiving Country (RC)	Waste Trader (WT)	United Nations (UN)	Non-Government Organizations (NGOs)
Preference Statements	4 5 2 IF -4 3 IF 2 7	-4 -6 -2	4 5 3 IF 2 7	4 2 IF -4 7

Having delivered data into the GMCRII, only one state satisfies all stability definitions, as shown in Figure 4.6.

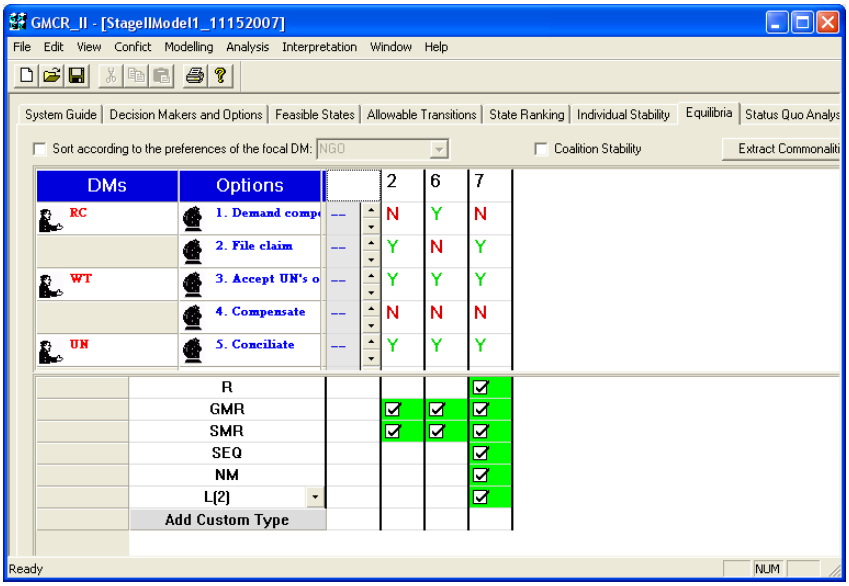

Figure 4.6. Model 2 in Stage II – Equilibria in GMCR II.

Table 4.9 summarizes the outcome of this model. Impelled by this resolution, the NGOs will launch a campaign against the international waste disposal. The Receiving Country prefers a legal procedure by filing a claim to the UN. The UN will seek a settlement as a mediator, since the Waste Trader does not agree to accept to compensate.

Table 4.9. Mode 2 – Summary of Equilibrium

DMs and Options	7
Receiving Country	
1. Demand compensation	N
2. File claim	Y
Waste Trader	
3. Accept UN's offer	Y
4. Compensate	N
United Nations	
5. Conciliate	Y
6. Arbitrate	N
Non-Government Organizations	
7. Campaign	Y

4.4.2. Model 3: Receiving Country has not Ratified the Basel Ban Amendment

The disposal dispute is not under the jurisdiction of the Basel Convention and its Amendments due to the Receiving Country not having ratified the convention. Accordingly, the available options to these four DMs are different from the options presented in Model 2. The Receiving Country has the option of demanding compensation, but it's less powerful than in Model 2. As well, the Receiving Country chooses to ratify the Basel Convention instead of filing a claim according to the convention. The Waste Trader may refuse or agree to compensate. The UN cannot put pressure on the Waste Trader directly, but may press the Receiving Country to ratify the Convention. The NGOs will call for public attention. The DMs and their corresponding options are presented in Table 4.10.

In this case, there are no infeasible state needs to be removed. Table 4.11 lists all the 32 feasible states of this conflict.

Table 4.10. Model 3 in Stage II – DMs and Options

DMs	Options
Receiving Country (RC)	1. Demand compensation: Insist that the trader compensate, including cleaning up and paying penalty. 2. Ratify: Ratify the Convention.
Waste Trader (WT)	3. Compensate: Agree to compensate and accept punishments.
United Nations (UN)	4. Press: Bring pressure on RC to ratify the Convention.
Non-Government Organizations (NGOs)	5. Campaign: Call for public attention to WT and press it to stop dumping.

Table 4.11. Feasible States of Model 3 in Stage II

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Receiving Country																
1.Demand compensation	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2.Ratify	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Waste Trader																
3.Compensate	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
United Nations																
4.Press	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Non-Government Organizations																
5.Campaign	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Receiving Country																
1.Demand compensation	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2.Ratify	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Waste Trader																
3.Compensate	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
United Nations																
4.Press	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Non-Government Organizations																
5.Campaign	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 4.12 describes the preference statements for option prioritization in this model. As shown, the Receiving Country most prefers that the Waste Trader agrees to compensate and pays all of the punishments, followed by the NGOs call for public attention to the Waste Trader and press it to stop dumping. Then, the Receiving Country would like to insist that the Waste Trader compensates and ratifies the Convention. For the Waste Trader, it would like other DMs not conduct any action against it. The United Nations and NGOs, basically, have the same preferences. The only difference is that NGOs want the Receiving Country to demand the compensation from the Waste Trader.

Table 4.12. Model 3 in Stage II – Preference Statements for Option Prioritization

DMs	Receiving Country (RC)	Waste Trader (WT)	United Nations (UN)	Non-Government Organizations (NGOs)
Preference Statements	3 5 1 2	-3 -2 -5 -4	3 2 IF 4 5	3 1 2 IF 4 5

Having delivered data into the GMCRII, two possible resolutions satisfy all stability definitions, as shown in Figure 4.7. In addition, Table 4.13 summarizes the outcome of this model. Both possible resolutions suggest that UN may or may not push the Receiving Country to ratify the Basel Convention for a full ban on the toxic waste dumping in the future. And the Receiving Country will claim a compensation for its loss and ratify the Convention for future protection. However, the Waster Trader will refuse

to compensate. In addition, the NGOs will launch a campaign to against the Waster Trader.

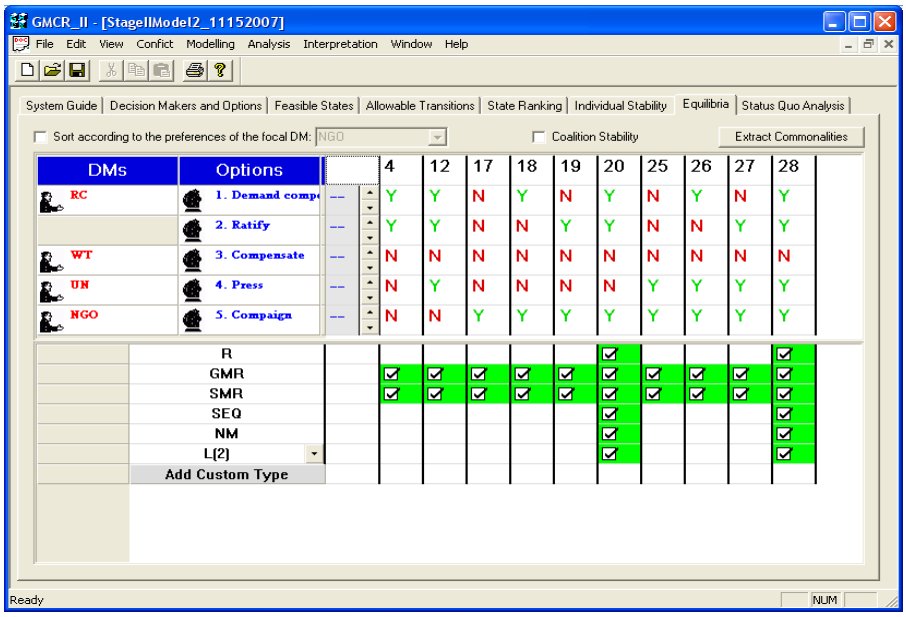

Figure 4.7. Model 3 in Stage II – Equilibria in GMCR II.

Table 4.13. Model 3 in Stage II – Summary of Equilibria

DMs and Options	20	28
Receiving Country		
1. Demand compensation	Y	Y
2. Ratify	Y	Y
Waste Trader		
3. Accept compensation	N	N
United Nations		
4. Press	N	Y
Non-Government Organizations		
5. Campaign	Y	Y

4.5. Summary

In this chapter, a generic multi-stage approach, consisting of three specific analytical models, is developed and analyzed by employing the methodology of GMCR. A real-world case study of Ivory Coast toxic waste dumping dispute is investigated in the next chapter in order to illustrate how to implement this generic approach in practice.

Chapter 5 Case Study: Ivory Coast Toxic Waste Dumping Scandal

Ivory Coast was once one of the most prosperous countries in West Africa. However, political turmoil and civil war destroyed the wealth and social structure of this country (Central Intelligence Agency, 2007). A recent environmental crisis has worsened the situation even further. In August 2006, Abidjan, the largest city and economic capital of Ivory Coast, experienced a tragedy caused by toxic waste dumping. As of October 2006, at least 10 people had died and thousands had sought medical treatment (Johnson, 2006; MacKenzie, 2006; Polgreen and Simons, 2006). This horrible event caused a global uproar over the growing trade in hazardous wastes.

The Ivory Coast toxic waste dumping case reveals a complex conflict that entangles different parties (local government, toxic waste trader, the United Nations and Non-Governmental Organizations) representing the areas of finance, law and the environment. In this chapter, the developed generic graph model is applied to study this dispute. With some adjustments, according to the specific situations, insights are generated. Through this case study, the method for implementation of the generic model as well as the model's practicability are illustrated and discussed.

5.1. Background

Ivory Coast, officially called République de Côte d'Ivoire, is a western African country. Figure 5.1 shows a map of Ivory Coast. According to the World Factbook (Central Intelligence Agency, 2007), it was once one of the most prosperous countries due to its cocoa production exports and related foreign investment. Currently, it is still one of the world's largest producers and exporters of coffee, cocoa beans, and palm oil. However, from December 1999 to 2003, a military coup, a political stalemate, and other issues sparked the civil war, which destroyed the country's economic development and the lives of its people. Presently, some of these issues remain unresolved, and thousands of French and West African troops remain in Ivory Coast for the purpose of peacekeeping and other military related processes.

Nevertheless, the situation in this country was further deteriorated by a recent environmental crisis, more specifically, a toxic waste dumping event. In August 2006, 400 tons of mixtures of gasoline, water and caustic washings used to clean oil drums were dumped in at least 10 sites around the city of Abidjan (African News Dimension, 2006). Tragically, as a result, no less than 10 people died, dozens were hospitalized and more than 85,000 sought medical treatment for nausea, vomiting and headaches due to the toxic fumes from hydrogen sulphide, petroleum distillates and sodium hydroxide (Johnson, 2006; MacKenzie, 2006; Polgreen and Simons, 2006). According to the reports of Green Peace and several major media organizations, a ship, named Probo Koala, was identified as the culprit. This Greek-managed and Panamanian-flagged ship was leased by a Dutch-based company named Trafigura Beheer B.V., one of the world's

leading commodity traders specializing in petrol, gasoline and base metals (Doyle, 2006). It maintains over 58 offices in 46 countries throughout Europe, North, Central and South America, Africa, Asia and Australia (UN Integrated Regional Information Networks, 2006).

Figure 5.1. Map of Ivory Coast (Central Intelligence Agency, 2004)

5.2. Model Building

The model developed in this chapter analyzes the situation at the beginning of November, 2006. At that point in time, the dumping had already occurred, and the receiving country, Ivory Coast, had not yet ratified the 1995 Ban Amendment. Therefore, this model can be referred as the Model 3 of Stage II, Dispute Resolution Stage, according to the multi-stage graph model discussed in Chapter 4.

The involved DMs and corresponding options are listed in Table 5.1. The decision support system, GMCR II, is used in this thesis to facilitate the graph model analysis. Figure 5.2 shows the interface of DMs and options in GMCR II.

Table 5.1. Ivory Coast Conflict - DMs and Options

DMs	Options
Ivory Coast (IC)	1. Refuse Waste: Refuse future toxic waste dumping.
	2. Demand compensation: Insist that the trader compensate, including cleaning up and paying penalty.
	3. Enforce: Ratify the 1995 Ban Amendment.
Toxic Waste Trader (TR)	4. Compensate: Agree to compensate and accept punishments.
United Nations (UN)	5. Press Ivory Coast: Put pressure on Ivory Coast to ratify the 1995 Ban Amendment.
Non-Government Organizations (NGOs)	6. Campaign: Call for public attention to Trader and press it to stop dumping.

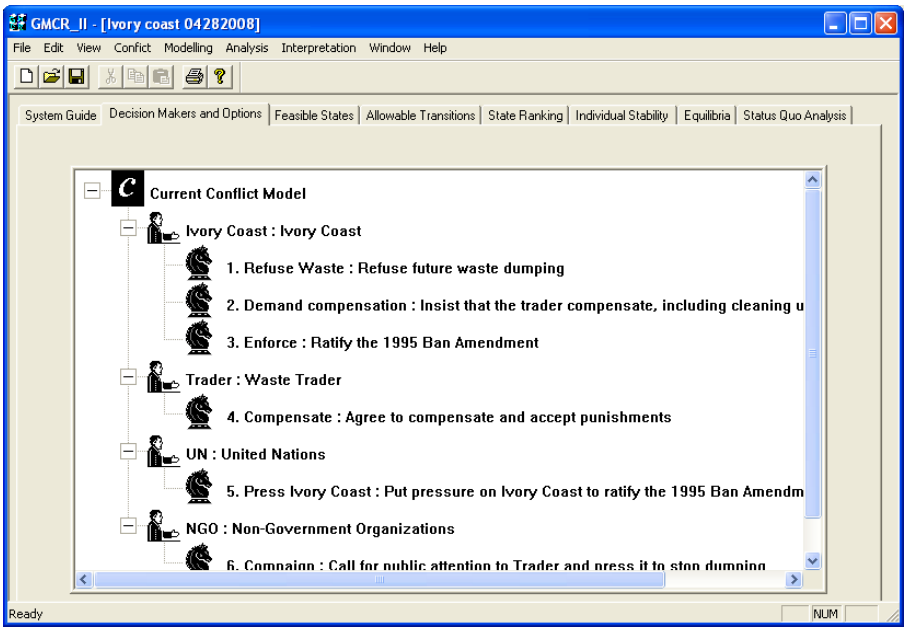

Figure 5.2. GMCR II – DMs and Options

5.3. Specify Infeasibilities

GMCR II provides four techniques to remove infeasible states. Three of the techniques, Mutually Exclusive, "At least one" Option, and Option Dependence, are employed in this case study as shown in Figure 5.3.

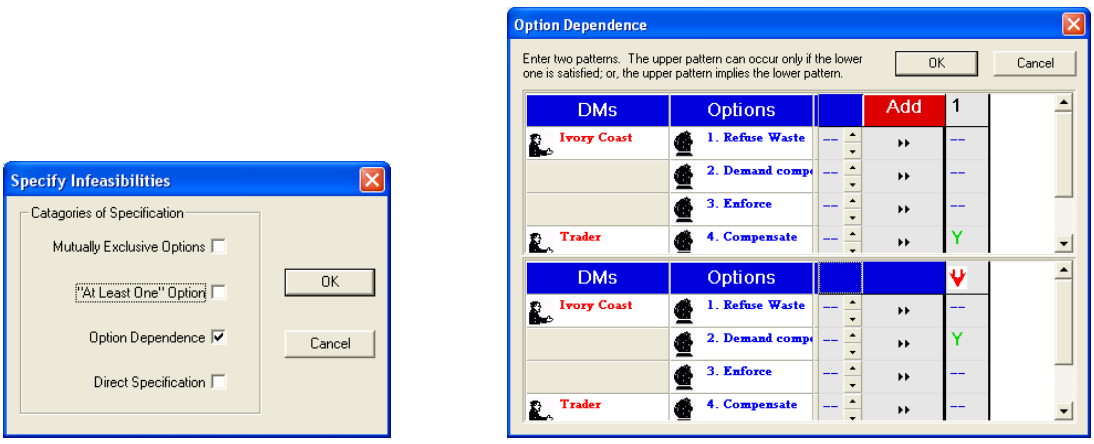

Figure 5.3. GMCR II – Specify Infeasibilities

For the Toxic Waste Trader, at least one option has to be chosen, Furthermore, only when Ivory Coast demands compensation will the Toxic Waste Trader choose to compensate. The reason is quite obvious: if there is no punishment at all, how can the company accept to compensate? After removing all infeasible states, 48 feasible states are retained and shown in Table 5.2.

Table 5.2. Ivory Coast Conflict - Feasible States

Options	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ivory Coast																								
1. Refuse waste	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2. Demand compensation	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y
3. Enforce	N	N	N	N	Y	Y	Y	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	Y	Y
Waste Trader																								
4. Compensate	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y
United Nations																								
5. Press Ivory Coast	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Non-Governmental Organizations																								
6. Campaign	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Options	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Ivory Coast																								
1. Refuse waste	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2. Demand compensation	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y
3. Enforce	N	N	N	N	Y	Y	Y	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	Y	Y
Waste Trader																								
4. Compensate	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y
United Nations																								
5. Press Ivory Coast	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Non-Governmental Organizations																								
6. Campaign	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

5.4. Preferences

There are three techniques provided by GMCR II to generate the preference profile in different situations: Option Weighting, Option Prioritizing, and Direct Ranking. In this section, Option Prioritizing is chosen to estimate the preference ranking in this conflict. Table 5.3 depicts preferences for each DM. Detailed explanations are presented below.

Table 5.3. Ivory Coast Conflict – Preference Statements for Option Prioritization

DMs	Ivory Coast (IC)	Toxic Waste Trader (TR)	United Nations (UN)	Non-Government Organizations (NGOs)
Preference Statements	4 6 1 2 3 IF 5	-2 -4 IF 2 -1 -3 IF 5 -6	4 3 IF 5 1 6	4 2 1 3 IF 5 6

Facing such a serious toxic pollution situation, Ivory Coast most prefers that Trader agrees to compensate, accepts the punishment, and then, stops any future dumping action. Next, the NGOs call for public attention to be brought to bear on the Trader and thereby to pressure it to stop dumping. Ivory Coast itself refuses any more dumping, demands compensation, and ratifies the 1995 Amendment when requested to do so by the UN.

From the Trader's point of view, the most preferred option is that Ivory Coast does not demand any compensation at all. Secondly, the Trader would like to refuse to provide any compensation requested by Ivory Coast and does not want Ivory Coast refuse the future dumping or to ratify the Amendment. It is also preferred by the Trader

that the NGOs not seek publicity to pressure the Trader to stop dumping.

For the UN, its first preference is that the Trader accepts the compensation and punishment. It would then prefer to see Ivory Coast ratify the Amendment in order that Ivory Coast may enjoy protection from any further toxic dumping through the protection offered by international law. Next, the UN prefers that the Trader accepts any punishment it imposes. Finally, the UN wants Ivory Coast to refuse dumping and the NGOs to seek publicity to pressure the Trader to stop dumping.

As for the NGOs, they most prefer that the Trader agree to compensate and accept punishment. Secondly, they prefer that Ivory Coast demand compensation, refuse any future dumping, and ratify the Amendment if the UN asks it to do so. Finally, the NGOs definitely want to call for public attention to be applied to the Trader thereby pressuring it to stop dumping.

5.5. Stability Analysis

Once the preference profiles for all DMs are determined, GMCR II is ready to attain the stability and equilibria results for this problem. In this case study, only state 44 is strongly stable under all stability definitions (Table 5.4, Figure 5.7). As shown, Ivory Coast will refuse any future waste dumping, demand the Trader to compensate, and ratify the 1995 Amendment. The Trader will try to refuse to compensate. The United Nations will put pressure on Ivory Coast and request it to ratify the Amendment for future protection. The Non-Government Organizations will definitely call for public attention to be applied to the Trader thereby pressuring it to stop dumping.

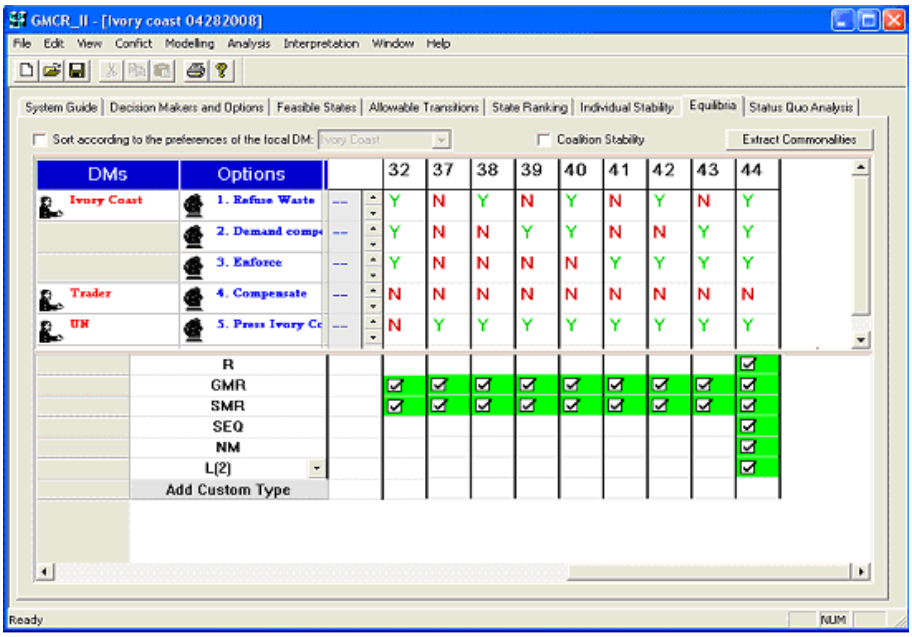

Figure 5.7. GMCR II – Equilibrium

Table 5.4. Ivory Coast Conflict - Summary of Equilibrium

Options	44
Ivory Coast	
1. Refuse waste	Y
2. Demand compensation	Y
3. Enforcement	Y
Waste Trader	
4. Compensate	N
United Nations	
5. Press Ivory Coast	Y
Non-Governmental Organizations	
6. Campaign	Y

5.6. Attitude Analysis

As introduced in Chapter 3, consideration of the attitudes of DMs along with the regular stability analysis is a very useful expansion for better understanding a given

conflict situation. In the Ivory Coast waste dumping dispute, the application of the attitude analysis may demonstrate how the states of a conflict are dependent upon the attitudes of DMs. By comparing attitude analysis with the conventional conflict analysis, changes may occur in the resolution of the conflict due to the consideration of the social and psychological factors in the conflict. According to the definitions of the attitude analysis, the standard analysis is considered as "rational", based upon an assumption that all DMs are rational. Specifically, each DM in this situation is positive towards itself and neutral towards its opponents. In this section, in order to gain a comprehensive understanding of the Ivory Coast dispute, it is re-analyzed and discussed from the attitude perspective in detail.

5.6.1. Attitudes in the Ivory Coast Conflict

Attitudes of all DMs within this dispute are shown in Table 5.5. Each entry of this table stands for the attitude of the column DM towards the row DM. It is quite intuitive to obtain this attitude information from the real situation. For example, in the first column, the receiving country, Ivory Coast, has a negative attitude towards the Trader, while is indifferent with respect to itself and other DMs. Similarly, the Trader is negative towards Ivory Coast and indifferent with respect to itself and other DMs. The United Nations and the Non-Government Organization are indifferent to all DMs.

Table 5.5. Attitudes in the Ivory Coast Waste Dumping Conflict

	IC	TR	UN	NGOs
IC	$e_{IC,IC} = 0$	$e_{IC,TR} = -$	$e_{IC,UN} = 0$	$e_{IC,NGO} = 0$
TR	$e_{TR,IC} = -$	$e_{TR,TR} = 0$	$e_{TR,UN} = 0$	$e_{TR,NGO} = 0$
UN	$e_{UN,IC} = 0$	$e_{UN,TR} = 0$	$e_{UN,UN} = 0$	$e_{UN,NGO} = 0$
NGOs	$e_{NGO,IC} = 0$	$e_{NGO,TR} = 0$	$e_{NGO,UN} = 0$	$e_{NGO,NGO} = 0$

5.6.2. Relational Stability Analysis

Containing the attitude information, a stability analysis tableau, as illustrated in Table 5.7, can be constructed. For each DM, all of the states are shown from the most to least preferred. Beneath these states, all of the possible UIs (see details in Chapter 3) from the particular state are listed. For instance, Ivory Coast can get preference improvement by unilaterally moving from state 43 to 40 or 44. Additionally, for explanation purposes, the reachable lists of each state for all DMs are displayed in Table 5.6. For example, state 43 has the reachable lists of $R_{IC}(43) = \{37,38,39,40,41,42,44\}$, $R_{TD}(43) = \{47\}$, and $R_{UN}(43) = \{31\}$, $R_{NGO}(43) = \{19\}$, for Ivory Coast, the Trader, the United Nations, and the Non-Government Organizations, respectively. The reachable lists describe the set of unilateral movements from a specific state, which are referred to as the rational response list, $TRR(e_i)(s)$, in the attitude analysis. Now, state 43 is taken as an example to demonstrate the detailed investigation by implementing the relational definitions of attitude analysis introduced in Chapter 3.

For Ivory Coast, it has a negative attitude towards the Trader. Related to state 43,

the Trader's preference states $42 \succ_{TR} 43$ and $38 \succ_{TR} 43$. So, $44,40\ \mathrm{RP}\left(e_{IC,TR} = -\right)43$. Furthermore, as states 44 and 40 are relational preferred states at state 43 for Ivory Coast with respect to all DMs in the conflict, $44,40\ \mathrm{TRP}\left(e_{IC}\right)43$ and, thus, $\mathrm{TRR}\left(43\right)_{IC} = \left\{43,44,40\right\}$. For the Trader, state 43 has the reachable list of $R_{TD}\left(43\right) = \left\{47\right\}$. Being neutral to itself, the Trader prefers state 43 to 47. Also, as the Trader has a negative attitude towards Ivory Coast, Ivory Coast's preferences must be examined to determine the Trader's relational reply with respect to Ivory Coast. As shown in Table 5.7, $47 \succ_{IC} 43$. Hence, it can be obtained that $\mathrm{TRR}\left(43\right)_{TR} = \left\{43\right\}$, which indicates that state 43 is RNash stable for the Trader. Similarly, since the other two DMs are neutral to all DMs, it is easy to see that state 43 is RNash for both of them. However, as Ivory Coast does not have the set where $\mathrm{TRR}\left(43\right)_{IC} = \left\{43\right\}$, state 43 is not RNash stable in this problem.

Furthermore, since $\mathrm{TRR}\left(43\right)_{IC} = \left\{43,44,40\right\}$, the only movement that can be done by Ivory Coast is from state 43 to state 40 or 44. From state 40, the Trader has no total relational replies, i.e., Trader cannot sanction Ivory Coast to make this movement. Thus, there exists no RSEQ stabilities for each Ivory Coast. When it comes to RGMR and RSMR stabilities for Ivory Coast, again, the only movement can be carried out by Ivory Coast from state 43 is to move to state 40 or 44. For all of the other DMs, both states 40 and 44 are sanctioned and cannot move to any other state. This shows that state 43 is both RGMR and RSMR for Ivory Coast.

Table 5.6. Reachable Lists

States	Ivory Coast							Trader	UN	NGOs
1	2	3	4	5	6	7	8		13	25
2	1	3	4	5	6	7	8		14	26
3	1	2	4	5	6	7	8	9	15	27
4	1	2	3	5	6	7	8	10	16	28
5	1	2	3	4	6	7	8		17	29
6	1	2	3	4	5	7	8		18	30
7	1	2	3	4	5	6	8	11	19	31
8	1	2	3	4	5	6	7	12	20	32
9	10	11	12					3	21	33
10	9	11	12					4	22	34
11	9	10	12					7	23	35
12	9	10	11					8	24	36
13	14	15	16	17	18	19	20		1	37
14	13	15	16	17	18	19	20		2	38
15	13	14	16	17	18	19	20	21	3	39
16	13	14	15	17	18	19	20	22	4	40
17	13	14	15	16	18	19	20		5	41
18	13	14	15	16	17	19	20		6	42
19	13	14	15	16	17	18	20	23	7	43
20	13	14	15	16	17	18	19	24	8	44
21	22	23	24					15	9	45
22	21	23	24					16	10	46
23	21	22	24					19	11	47
24	21	22	23					20	12	48
25	26	27	28	29	30	31	32		37	1
26	25	27	28	29	30	31	32		38	2
27	25	26	28	29	30	31	32	33	39	3
28	25	26	27	29	30	31	32	34	40	4
29	25	26	27	28	30	31	32		41	5
30	25	26	27	28	29	31	32		42	6
31	25	26	27	28	29	30	32	35	43	7
32	25	26	27	28	29	30	31	36	44	8
33	34	35	36					27	45	9
34	33	35	36					28	46	10
35	33	34	36					31	47	11
36	33	34	35					32	48	12
37	38	39	40	41	42	43	44		25	13
38	37	39	40	41	42	43	44		26	14
39	37	38	40	41	42	43	44	45	27	15
40	37	38	39	41	42	43	44	46	28	16
41	37	38	39	40	42	43	44		29	17
42	37	38	39	40	41	43	44		30	18
43	37	38	39	40	41	42	44	47	31	19
44	37	38	39	40	41	42	43	48	32	20
45	46	47	48					39	33	21
46	45	47	48					40	34	22
47	45	46	48					43	35	23
48	45	46	47					44	36	24

For each single state, Table 5.7 is employed to carry out all these analyses and to check all of the four stability definitions. The results are depicted in Table 5.8.

From Table 5.8, note that the same equilibrium, as the previous calculation without considering the attitude information, state 44 is achieved. This result confirms the consistency of our calculations and the robustness of this analytical model.

Table 5.7. Relational Stability Analysis Tableau

$$e_1 = (e_{11} = 0, e_{12} = -, e_{13} = 0, e_{14} = 0), \quad e_2 = (e_{21} = -, e_{22} = 0, e_{23} = 0, e_{24} = 0),$$

$$e_3 = (e_{31} = 0, e_{32} = 0, e_{33} = 0, e_{34} = 0), \quad e_4 = (e_{41} = 0, e_{42} = 0, e_{43} = 0, e_{44} = 0)$$

	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	E	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	RN	RN	RN	U	U	U	U	U	RN	RN	RN	U	U	RN	U	U	RN	RN	RN	U	U	U	U	U	U	U	U	U	U	U	RN	RN	RN	U	U	U	U	U	U	U	U	U	U
Ivory	48	36	34	46	33	35	47	45	12	24	10	22	9	11	23	21	44	28	32	40	43	31	27	39	42	26	30	38	41	29	25	37	4	8	20	16	19	3	7	15	2	18	6	14	5	17	1	13
Coast				48	34	36	48	48				24	10		24	24				44	44	28	28	44	44	28	28	44	44	28	28	44				20	20	4	4	20	4	20	4	20	4	20	4	20
							46	46							22	22				40	32	32	40	40	40	32	32	40	40	32	32	40						16	8	8	16	8	16	8	16	8	16	8	16
								47							23								42	43	21	21	42	42	26	26	42								18	3	19	3	18	2	18	2	18
																							38	39	27	27		38	30	30	38								14	7	15	7		6	14	6	14
																							43					43	31	31	43								19					3	19	3	19
																												39	27	27	39													7	15	7	15
																															41															17

	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	U	U	U	U	U	U	U	U	U	U	U	U	U
Trader	1	5	13	29	37	25	17	41	14	2	6	30	26	38	18	42	3	15	7	31	39	27	19	43	16	4	8	28	40	32	20	44	9	21	11	35	33	45	23	47	12	22	10	34	36	46	24	48
																																	3	15	7	31	27	39	19	43	8	16	4	28	32	40	20	44

	RN	RN	RN	RN	RN	RN	RN	RN	U	U	U	U	U	U	U	U	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	U	U	U	U	U	U	U	U	U	U	U	U	U
UN	48	27	47	23	46	22	45	21	34	36	12	10	35	33	9	11	42	44	20	18	41	43	19	17	40	38	16	14	37	39	13	15	28	26	30	32	4	2	8	6	31	27	29	25	3	5	7	1
									46	48	24	22	47	45	21	23																	40	38	42	44	16	14	20	18	43	39	41	37	15	17	19	13

	RN	RN	RN	U	U	U	RN	U	RN	RN	RN	U	U	RN	U	RN	RN	RN	RN	U	U	U	RN	U	RN	RN	RN	U	U	U	RN	U	RN	RN	RN	U	U	U	RN	U
NGOs	48	32	36	12	8	24	44	20	31	35	47	7	23	11	43	19	34	30	46	10	22	6	42	18	29	45	33	9	5	21	41	17	40	26	28	16	4	2	38	14	27	39	25	15	1	3	37	13
				36	32	48		44				31	47	35		43				34	46	30		42				33	29	45		41				40	28	26		38				39	25	27		37

Table 5.8. Stability and Equilibrium

States	RNash	RSEQ	RSMR	RGMR	# of EQ
1	TR, NGOs	TR, NGOs	TR, NGOs	TR, NGOs	0
2	TR, NGOs	TR, NGOs	TR, NGOs	TR, NGOs	0
3	TR	TR	TR, NGOs	TR, NGOs	0
4	TR	TR	TR, NGOs	TR, NGOs	0
5	TR	TR, NGOs	TR, NGOs	TR, NGOs	0
6	TR	TR, NGOs	TR, NGOs	TR, NGOs	0
7	TR	TR, NGOs	TR, NGOs	TR, NGOs	0
8	IC, TR	IC, TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
9	IC	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
10		IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
11	IC	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
12		IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
13	TR, UN	TR, UN	TR, UN	TR, UN	0
14	TR, UN	TR, UN, NGOs	TR, UN, NGOs	TR, UN, NGOs	0
15	TR, UN	TR, UN, NGOs	TR, UN, NGOs	TR, UN, NGOs	0
16	TR, UN	TR, UN	TR, UN, NGOs	TR, UN, NGOs	0
17	TR, UN	TR, UN	TR, UN, NGOs	TR, UN, NGOs	0
18	TR, UN	TR, UN, NGOs	TR, UN, NGOs	TR, UN, NGOs	0
19	TR, UN	TR, UN, NGOs	TR, UN, NGOs	TR, UN, NGOs	0
20	IC, TR, UN	IC, TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	3
21	IC, UN	IC, UN	IC, UN, NGOs	IC, UN, NGOs	0
22	UN	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
23	UN	IC, UN, NGOs	IC, UN, NGOs	IC, UN	0
24	UN	IC, UN, NGOs	IC, UN, NGOs	IC, UN	0
25	IC, TR	IC, TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
26	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
27	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
28	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
29	IC, TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
30	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
31	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
32	TR, NGOs	TR, NGOs	IC, TR, NGOs	IC, TR, NGOs	0
33	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
34	, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
35	IC, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
36	NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
37	IC, TR, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	3
38	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
39	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
40	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
41	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
42	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
43	TR, UN, NGOs	TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	2
44	IC, TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	IC, TR, UN, NGOs	4
45	UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
46	UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
47	UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0
48	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	IC, UN, NGOs	0

5.7. Summary

In this chapter, a case study of the Ivory Coast toxic waste dumping conflict is analyzed by using the generic model for the international toxic waste disposal. In addition to the regular stability analysis, the attitudes aspect is also taken into consideration. This attitude analysis further confirms the analysis resolution and enhances the understanding of this dispute.

Chapter 6 Conclusions and Future Work

In this thesis, a multi-stage generic graph model for international toxic waste disposal conflicts is developed and analyzed. More specifically, the model divides toxic waste disputes into two stages consisting of the dumping prevention and dispute resolution stages. Then, the practical conflict analysis methodology, the Graph Model for Conflict Resolution, is employed in both stages to carry out in-depth investigations at the strategic level of decision making. Additionally, a case study of the Ivory Coast toxic waste dumping controversy, a recent real-world scandal, is used to demonstrate how to implement this multi-stage generic model in practice.

6.1. Contributions

The main contributions of this thesis are as follows.

1) A multi-stage generic graph model is developed to investigate the international toxic waste disposal conflict. Rather than only analyzing the conflict afterwards, this model takes both the prevention and resolution stage into consideration. Through comprehensive analyses over different stages, the proposed model assists the DMs and other interested parties in making informed decisions and facilitates in providing making them with a better understanding of the conflict situation.

2) In the problem resolution stage, two graph models are built corresponding to the different status of the waste receiving countries, which the most important participants in the international toxic waste disposal conflict. Some receiving countries have already ratified the Basel Convention, while others have not. Due to this difference, both of these countries and the United Nations would have dissimilar options and preferences. Therefore, two models are presented in this thesis in order to solve this problem. Note that feedback is allowed when one model has obtained resolution.

3) Attitude issues are taken into account along with the regular graph model analysis. Attitudes may have great impact on any conflict situation. Employing the graph model analysis accompanied with attitudes assists DMs and other interested parties to understand the given situations more thoroughly and to ascertain the plausibility of the predicted equilibria, or resolutions. The investigation further confirms the achieved resolutions and the robustness of the proposed model.

4) In addition to three regular DMs, the NGOs are considered in the generic model. Nowadays, more and more NGOs are dedicated to improving the global environment. Their efforts are impressive and, therefore, cannot be ignored.

5) A real-world case, the Ivory Coast toxic waste dumping problem, is investigated by using a specific sub-model of the proposed generic graph model, model 3 of the dispute resolution stage. With further considerations of the attitude analysis, the model suggests each DM's possible future tendency of the current situation. Thus, the validity and practicability of the model (Stage 2 only) are illustrated.

6.2. Future Work

Due to the potentials of high profits, the toxic waste trading will continue to be attractive and, thus, exist for a relatively long term (Asante-Duah and Nagy, 1998). Besides the toxic waste conflict that we analyzed in this thesis, there are other related conflicts occurring worldwide. For example, as an international law, the Basel Convention and Ban Amendment is actually an environmental agreement. In many case, there exists some debate concerning the jurisdiction and scope of the Basel Convention and Ban Amendment. It is inevitable that conflicts will arise due to the overlap of the environmental agreement and the agreements of the World Trade Organization. Furthermore, the existing dispute settlement methods of the UN may also cause conflict.

Additionally, because of the improvement of international law, the situation of international waste trading contains more and more uncertain issues, especially the preference information of different DMs. Li et al. (2004a) introduced a binary relation to represent the uncertain preference of an involved DM. Four graph-model stability concepts are also redefined based on this uncertain preference structure. It would be an interesting yet challenging task to integrate the uncertainty into our generic model.

Furthermore, in modeling conflicts, the consideration of nations where toxic wastes originate or toxic waste traders are based in could be a factor in some particular cases. Because these nations may have enacted legislations on controlling toxic waste trading, their governments may be able to take actions. In those particular cases, the government should be included as a DM in a conflict model.

Moreover, the dynamic nature of the toxic waste trading problem causes significant

complexity in tackling, especially from the international perspective (Clapp, 2001). So considering the misperceptions between the DMs would be another possible applicable future research topic.

Finally, it should be mentioned that the world would become more secure and peaceful if the hazardous waste problem could be solved at its root, the generation of toxic wastes, instead of fixing it after the occurrence. The employment of some particular techniques to reduce the generation of toxic wastes and, maybe, even slow down the pace of industrialization would be reasonable and helpful (Clapp, 2001).

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