Emotion, Perception and Strategy in Conflict Analysis and Resolution

by

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Amer Obeidi

Abstract

Theoretical procedures are developed to account for the effect of emotion and perception in strategic conflict. The *possibility principle* facilitates modeling the effects of emotions on future scenarios contemplated by decision makers; *perceptual graph models* and a *graph model system* permit the decision makers (DMs) to experience and view the conflict independently; and *perceptual stability analysis*, which is based on individual- and meta-stability analysis techniques, is employed in analyzing graph model systems when the DMs have inconsistent perceptions. These developments improve the methodology of the Graph Model for Conflict Resolution by reconciling emotion, perception, and strategy to make predictions consistent with the actual unfolding of events.

Current research in neuroscience suggests that emotions are a necessary component of cognitive processes such as memory, attention, and reasoning. The somatic marker hypothesis, for example, holds that feelings are necessary to reasoning, especially during social interactions (Damasio, 1994, 2003). Somatic markers are memories of past emotions: we use them to predict future outcomes. To incorporate the effect of emotion in conflict, the underlying principle of Damasio's hypothesis is used in developing the possibility principle, which significantly expands the paradigm of the Graph Model for Conflict Resolution of Fang, Hipel, and Kilgour (1993).

State identification is a crucial step in determining future scenarios for DMs. The possibility principle is integrated into the modeling stage of the Graph Model by refining the method of determining feasible states. The possibility principle enables analysts and DMs to include emotion in a conflict model, without sacrificing the parsimonious design of the Graph Model methodology, by focusing attention on two subsets of the set of feasible states:

hidden and *potential* states. Hidden states are logically valid, feasible states that are invisible because of the presence of negative emotions such as anger and fear; potential states are logically valid, feasible states that are invisible because of missing positive emotions. Dissipating negative emotions will make the hidden states visible, while expressing the appropriate positive emotions will make the potential states visible. The possibility principle has been applied to a number of real world conflicts. In all cases, eliminating logically valid states not envisioned by any DM simplifies a conflict model substantially, expedites the analysis, and makes it an intuitive and a realistic description of the DMs' conceptualizations of the conflict.

A fundamental principle of the Graph Model methodology is that all DMs' directed graphs must have the same set of feasible states, which are integrated into a *standard* graph model. The possibility principle may modify the set of feasible states perceived by each DM according to his or her emotion, making it impossible to construct a single standard graph model. When logically valid states are no longer achievable for one or more DMs due to emotions, the apprehension of conflict becomes inconsistent, and resolution may become difficult to predict. Therefore, reconciling emotion and strategy requires that different apprehensions of the underlying decision problem be permitted, which can be accomplished using a perceptual graph model for each DM. A perceptual graph model inherits its primitive ingredients from a standard graph model, but reflects a DM's emotion and perception with no assumption of complete knowledge of other DMs' perceptions.

Each DM's perceptual graph model constitutes a complete standard graph model. Hence, conclusions drawn from a perceptual graph model provide a limited view of equilibria and predicted resolutions. A graph model system, which consists of a list of DMs' perceptual graph models, is defined to reconcile perceptions while facilitating conclusions that reflect each DM's viewpoint. However, since a DM may or may not be aware that other graph models differ from his or her own, different variants of graph model systems are required to describe conflicts. Each variant of graph model system corresponds to a configuration of awareness, which is a set of ordered combinations of DMs' viewpoints.

Perceptual stability analysis is a new procedure that applies to graph model systems. Its objective is to help an *outside* analyst predict possible resolutions, and gauge the robustness and sustainability of these predictions. Perceptual stability analysis takes a two-phase approach. In Phase 1, the stability of each state in each perceptual graph model is assessed from the point of view of the owner of the model, for each DM in the model, using standard or perceptual solution concepts, depending on the owner's awareness of others' perceptions. (In this research, only perceptual solution concepts for the 2-decision maker case are developed.) In Phase 2, meta-stability analysis is employed to consolidate the stability assessments of a state in all perceptual graph models and across all variants of awareness. Distinctive modes of equilibria are defined, which reflect incompatibilities in DMs' perceptions and viewpoints but nonetheless provide important insights into possible resolutions of conflict.

The possibility principle and perceptual stability analysis are integrative techniques that can be used as a basis for empathetically studying the interaction of emotion and reasoning in the context of strategic conflict. In general, these new techniques expand current modeling and analysis capabilities, thereby facilitating realistic, descriptive models without exacting too great a cost in modeling complexity. In particular, these two theoretical advances enhance the applicability of the Graph Model for Conflict Resolution to real-world disputes by integrating emotion and perception, common ingredients in almost all conflicts.

To demonstrate that the new developments are practical, two illustrative applications to real-world conflicts are presented: the US-North Korea conflict and the confrontation between Russia and Chechen Rebels. In both cases, the analysis yields new strategic insights and improved advice.

Acknowledgements

Completing a doctorate degree is not about writing a thesis and defending it; these are the easy tasks. A doctorate degree is a long journey of commitments to learning, where an apprentice develops an understanding for a range of topics, but becomes an expert in only one. So many people become involved in making this journey worth the effort, to which I take this opportunity to thank them all. I would like to acknowledge the enthusiastic and enlightening supervision of Professor Keith W. Hipel and Professor D. Marc Kilgour. Their support, guidance, and companionship are instrumental in enabling me achieve what I aspired to. Their persistent guidance helped me in making valuable contributions. They encouraged me to adopt an interdisciplinary and systems approach to important research problems.

Dr. Hipel’s wisdom and perseverance have been sources of motivation. Above all, his supreme level of enthusiasm fascinates me and often inspires and challenges me. His teaching skills, passion for research and sensitivity to students’ needs always amazes me. His optimism and dynamic personality are contagious. He is an ideal role model for aspiring scientists and academicians.

Equally, I am grateful to Dr. Kilgour for so many other things including enlightening discussions, moral support, and continuous advice. His sound judgment and meticulous and patient approach to research were instrumental to me in successfully completing this thesis. His extensive knowledge and experience, open mind and a sharp eye for the merit of ideas were particularly valuable in solving many of the challenges that I faced during developing my ideas. He always fascinates me by his eloquent style of writing and expression. I would like to thank him for his mentoring, support, and encouragement.

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Dedication

I dedicate this dissertation to my lovely wife, Reema,
and children: Yazan, Bassil, and Yara.

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Chapter 1

Introduction

> "We praise a man who feels angry on the right ground and against the right persons and also in the right manner at the right moment and for the right length of time." Aristotle (384-322 BC).

1.1 Predominance of Emotion in Conflict

Conflicts, ranging from benign differences of opinion to deadly confrontations, inevitably arise whenever human beings interact with one another in the course of managing their daily affairs. Disagreements among individuals over daily issues can easily change into hostile reactions as a result of the way situations are perceived, and the emotional values that are attached. For example, consider a community-based City Council. Often, controversies arise over the enforcement of bylaws affecting the socio-economic development and management of the city's resources. These controversies can easily escalate into a serious conflict, which creates a climate of enmity between citizens and City Councilors.

On the other extreme, instability and violence have brought suffering and humiliation to people all over the world, and often led to atrocities. The immediate consequences of these conflicts are, *inter alia*, fatalities, ethnic cleansing, poverty, hunger, human rights violations, and compulsory migrations. Diamond (2005) argues that the collapses of ancient civilizations such as the Maya in Central America, Great Zimbabwe in Africa, and Easter Island in the Pacific Ocean were mainly caused by failure to respond effectively to problems, and in particular by systematically making decisions that hindered survival. Hence, societal collapses were brought about by failures in group decision making mechanisms.

Nowadays, resource-driven conflicts predominate worldwide, in terms of both numbers and severity. During the 1990s, more than 5 million people were killed, 5 to 6 million were forced to flee to neighboring countries, and 11 to 15 million people were displaced inside borders of their home countries as a result of these conflicts (Renner, 2002). In most cases, a common denominator was the precipitated emotion of those involved in conflict. It is no wonder that conflict is often described as omnipresent and emotional.

Emotions play a central role in shaping human lives (Cacioppo and Gardner, 1999; Ekman, 1999; Izard, 1993). They determine how people conceptualize events in relation to their environment, and how they react and respond to these events. Emotions affect attention, beliefs, and actions, focusing and guiding memory (Clore and Gasper, 2000; Damasio, 1994) and influencing our cognitive processes. They shape and strengthen our beliefs (Frijda and Mesquita, 2000; Elster, 1999b), help us rearrange our priorities and revise our goal hierarchies (Simon 1976), influence our preferences, and act as a nexus among our beliefs, value systems, and wants, thereby strengthening our commitments. Finally, emotions tend to induce specific actions that restore equilibrium or balance (Elster, 1999a), including coping responses that enable us to manage the emotions themselves (Lazarus, 2001; Lazarus and Lazarus, 1994). For example, individuals naturally tend to eliminate the conditions that produce negative emotion: an angry person may seek revenge, creating an equilibrium by matching harm with harm (Allred, 1999).

Recent research in behavior, judgment, and decision making has recognized the effects of emotions on individuals' choices. A person's emotions at the moment of decision and his or her assessment of the risk associated with that decision are strongly correlated. Loewenstein, Weber, Hsee, and Welch (2001) posit that emotion often drives behavior in risky situations by mediating the cognitive assessment of risk. Lerner and Keltner (2001, 2000) developed an appraisal-tendency hypothesis of the effect of emotion on judgment that goes beyond a valence-based contrast of positive and negative emotions. Different emotions, they found, predispose individuals to assess the environment differently. For example, fear tends to make a decision maker pessimistic and risk averse, while anger leads to more optimistic risk assessments and risk-acceptant behavior (Lerner and Keltner, 2001).

As will be discussed in Chapter 4, there is an isomorphism between the characteristics that define and drive conflict and those that engender emotions. Emotions apply to something of relevance or interest to the decision maker, and are triggered by a large variety of stimuli within the self-environment relationship (Lazarus, 2001a,b). Specifically, negative emotion commences as a response to physical or psychological perception of someone else's blameworthy action as hindering personal goals or needs, especially if the obstruction has a long-term effect, seen as transgressing a norm, being unfair, or being illegitimate (Frijda, 1986, 1988). Conflict, on the other hand, is driven by the perceived incompatibility of something of relevance, and the interference of others on the achievement of one's goals. It is not surprising that these features also engender negative emotion, which tends to prevail during confrontations in a way that further exacerbate decision makers' perceptions of behavioral possibilities and available outcomes. Hence, conflict is often accompanied with such negative emotions as anger, fear, and frustration.

Although emotions shape and influence the way a conflict commences, continues, and is resolved, not until recently were emotions considered in the modeling and analysis processes. In particular, Howard, Bennett, Bryant, and Bradley (1992) proposed drama theory as a new approach that recognizes the importance of emotions in conflict. However, in drama theory emotions are the result of dilemmas facing the decision makers at the moment of declaring positions. In other words, in drama theory emotions in a conflict model are treated superficially (Inohara, 2000). The stance taken in this research is that emotions are inherent in conflict; a good conflict model must, therefore, include them.

Accordingly, the development of formal methodologies to address complex decision problems and disputes in a way that takes into account how decision makers conceptualize events in relation to their environment and how they react and respond to these events is crucial in building realistic models of conflict, and thereby providing better predictions and resolutions. That is the aim of this research.

1.2 Classical Approaches to Conflict Analysis

Since conflict is characteristic of every aspect of human life, research on conflict resolution has taken place in a wide variety of disciplines. A rich range of psychological, sociological, game theory, systems engineering and other models has been developed for studying conflict

(Hipel, 2002; Hipel and Obeidi, 2005). (For an overview of models investigating conflict and its resolution, refer to Conflict Resolution theme in the Encyclopedia of Life Support Systems (EOLSS).) In particular, many formal techniques that have been developed to analyze decision situations characterized by conflict of interest are founded upon various assumptions. *Game theory* (Von Neumann and Morgenstern, 1953) furnished an early set of mathematical tools to conceptualize conflict as a decision problem (Luce and Raiffa, 1957). It stresses the structural similarities between an interactive decision problem and a conflict: there are two or more players, each with some ability to choose between alternatives or courses of action; each available alternative is fully known to each player; each player has preferences over outcomes (usually expressed using Von Neumann-Morgenstern utilities); and each player makes choices conducive to his or her own goals, and expects the opponent to do likewise.

Other formal tools proposed to model and analyze interactive decision problems include *Metagame Theory* (Howard, 1971), *Conflict Analysis* (Fraser and Hipel, 1984), *Hypergame Analysis* (Bennett, 1977, 1980; Wang, Hipel, and Fraser, 1988), the *Graph Model for Conflict Resolution* (Fang, Hipel, and Kilgour, 1993), and *Drama Theory* (Bennett and Howard, 1996; Bryant, 2003; Howard, 1999; Howard, Bennett, Bryant, and Bradley, 1992). These methodologies are related to game theory, but differ in modeling assumptions or analysis principles. But they all share the game theory view of the meaning of conflict.

All of these conflict analysis techniques apply to conflict conceived as a multi-person, multi-objective decision problem. For example, disputes over environmental pollution or shared utilization and ownership of resources are decision situations involving stakeholders who can influence outcomes. For example, Obeidi, Hipel, and Kilgour (2006) applied the

Graph Model for Conflict Resolution on a dispute among the government of Canada, the Mi'kmaq First Nation, and commercial fishermen over lobster fishing rights in New Brunswick, Canada.

A new paradigm for describing conflict has emerged: the concept of *strategic conflict* model refers to a model of a real conflict that captures all relevant components as structural characteristics. Thus, a strategic conflict model describes the decision makers, their opportunities, and their objectives and values as represented through their preferences over outcomes. Game theory and other conflict analysis techniques focus on finding outcomes that are stable with respect to choices made in decision makers' interests. In this optimality sense, the approach incorporates rationality.

The limitations of mathematical models, which by necessity are formal, systematic, and abstract, are acknowledged by Luce and Raiffa (1957, p. 3): "Game theory does not, and probably no mathematical theory could, encompass all the diverse problems which are included in our brief characterization of conflict of interest." More recently, Raiffa (2002, p. xii) stated: "… for a long time I found the assumptions made in standard game theory too restrictive for it to have wide applicability." Game theory and related conflict analysis techniques incorporate models that emphasize the instrumental nature of conflicts, i.e., their structural features. While this reduction has proven useful and practical, these conflict models cannot account for the interpersonal and relational dynamics, or the turbulence engendered by these dynamics. Specifically, the concept of strategic conflict lacks an essential ingredient present in most conflicts of interest: emotion.

In addition, game-theoretic and related methods focus on strategic choice as a tool to an end, and therefore concentrate on substantive issues that are openly declared by the parties, to the exclusion of salient interpersonal issues. Emotions and their effects on the evolution of a situation are often ignored in attempts to resolve complex disputes and social problems, on the grounds that emotional build-ups are outside the purview of cognitive assessment. Simple disagreements or debates over mundane issues can be transformed into open hostility because of perceptions and emotional values attached to the issues by stakeholders. Hence, unless the effects of emotions are understood and incorporated into theories of decision making and conflict analysis techniques, it is impossible to fully understand phenomena such as social integration and confrontation.

1.3 Research Objectives

Among the aforementioned methodologies to model and analyze interactive decision problems, the Graph Model for Conflict Resolution is probably the simplest and most flexible, and therefore most capable of carrying out realistic strategic studies of actual conflict. Within the structure of a Graph Model, the basic ingredient for analysis is a *state*, which corresponds to a distinguishable outcome or scenario of the conflict. An important step in modeling a conflict is identifying the states. The set of feasible states is then used to represent the vertices in each decision maker's (DM's) directed graph. Other components of the Graph Model are state transitions and DMs' preferences with respect to the states. Subsequently, DMs' interactions are modeled as evolving from an initial state, or a *status quo*, through state transitions controlled by DMs until some final state is reached, which represents a resolution of the conflict. The stability of a state is assessed from a DM's viewpoint by examining potential moves and countermoves by other DMs to an initial move by the DM. In a standard graph model, a state that is stable for all DMs constitutes an equilibrium, which is equivalent to a potential resolution.

To capture a range of styles of decision making under conflict, various stability definitions (solution concepts) are used to assess the stability of a state for a given DM. A solution concept is a mathematical model, which consists of a set of rules for identifying a state at which a DM would stay, given that the state has been attained. The following solution concepts have been adapted to the paradigm of the Graph Model: Nash stability (Nash, 1950, 1951), general metarationality (Howard, 1971), symmetric metarationality (Howard, 1971), sequential stability (Fraser and Hipel, 1984), limited-move stability (Fang, Hipel, and Kilgour, 1993; Kilgour, 1985; Zagare, 1984), and non-myopic stability (Brams and Wittman, 1981).

The decision support system GMCR II (Hipel, Kilgour, Fang, and Peng, 1997; Fang, Hipel, Kilgour, and Peng, 2003a,b) allows the Graph Model methodology to be applied easily to real world disputes. GMCR II models a conflict using the option form of the Graph Model methodology, in which a state is a feasible combination of options (or courses of action). In a graph model in option form, feasible states are obtained by eliminating combinations of options that are logically invalid or otherwise infeasible. For example, if options are mutually exclusive, then any combination of them is considered infeasible; such a combination cannot be a state of a graph model.

A major objective of this research is to develop mathematical structures and definitions for conflict modeling and analysis that accurately and rigorously include emotions within the paradigm of the Graph Model for Conflict Resolution. These new theoretical will advances expand the modeling and analysis algorithms by accounting for the consequences of emotions and perceptions on the actions that are perceived to be available, as well as actual choices.

A key postulate in this research is that central to any conflict are affective reactions, which occur when opponents endeavor to manage, control, and cope with the situation. Drawing upon different fields of study, conflict is viewed as a process triggered by an event or stimulus and evolving through different stages. Both emotion and reasoning are equally important in this process: emotion influences the conceptualization of the conflict in early stages, while reasoning dominates later stages. Hence, the process of conflict is characterized by a combination of perceived incompatible goals/needs (the perceptions of incompatibility) and interrelatedness in the accomplishments of these goals or needs (obstructions). Many psychology and neuroscience theories of emotion, particularly appraisal theory for emotion activation, argue that the characteristics of conflict intrinsically activate negative emotions (Lazarus, 2001a,b).

A DM's interaction and accompanying emotions affect how he or she explores and perceives the ambient realities of conflict, and the changes in it. Hence, a realistic model of a complex dispute must take into account reasoning and affective responses. In building a standard graph model, the feasible states are identified using a reasoning process. An *analyst* usually contemplates which states may actually occur in the conflict. Likewise, identifying the feasible states in a graph model in option form depends upon determining those combinations of options that are logically valid, while eliminating from the model those that are infeasible. To account for the role of emotion in affecting DMs' perceptions of outcomes, a new principle is introduced, based on studies of the inextricable relationship between cognitive and emotional processes. The *possibility principle* focuses attentions on feasible states that are not perceived by a DM either due to the presence of negative emotions or the lack of positive emotions. Hence, the possibility principle is a refinement to the method of identifying states that are recognized by a DM. It is expected that this refinement will simplify the modeling stage in the Graph Model. This line of research constitutes one major component of this thesis.

Within the framework of the standard Graph Model, it is assumed that all DMs share the same view of the conflict. Hence, all DMs' directed graphs have the same vertices, or states, which are often combined to form an integrated graph. But, the emotions that shape the DMs' apprehensions of states produce inconsistencies in perception across the DMs, making it impossible to integrate the individual graphs, as is commonly done in the standard graph model. Hence, each DM must have a private graph which for him or her represents the only model for the conflict. To accommodate this inconsistency in perceptions, each DM's graph is treated as a perceptual graph model. Moreover, the DM's awareness (or not) of other DMs' perceptions must be accounted for in the model. Under this conceptual framework, graph model systems are used to represent a conflict realistically. A graph model system consists of a list of all DMs' perceptual graph models, and includes specification of the viewpoint of each DM, i.e., whether or not he or she is aware that other DMs perceive the conflict differently. The pattern of inconsistencies of perception is called the variant of awareness. Another major contribution of this research, therefore, is the formal definition of a perceptual graph model and a graph model system, which allow the DMs to have different views of the conflict.

Perceptual stability analysis is developed to analyze a graph model system and to draw meaningful conclusions about: 1) states that are qualified to be resolutions for the conflict, and, 2) the sustainability of those resolutions across different combinations of awareness. Perceptual stability analysis consists of a two-phase approach for analyzing perceptual graph models, and employs meta-stability analysis to consolidate the findings of stability analysis in individual graphs. New stability and equilibrium definitions are introduced to accommodate the stability analysis procedure developed. In particular, perceptual solution concepts for the two-decision maker case are developed in detail. Perceptual stability analysis represents another major contribution of this research.

1.4 Outline of the Thesis

The main objective of this research is to broaden the Graph Model methodology into a new territory that takes into account the effects of emotion upon decision making under conflict. To the best of the author's knowledge, this line of research is completely original. Moreover, the theoretical advances in this research significantly enhance the applicability of the Graph Model for Conflict Resolution to real-world disputes.

The rest of the thesis is organized as follows. Chapter 2 begins with an overview of the Graph Model for Conflict Resolution and the various solution concepts that are used within it. In Chapter 3, a general definition for emotion is given. The neurobiological structures in the brain that are responsible for the activation of emotions and their homeostatic responses, as well as Damasio's somatic marker hypothesis, are also discussed. Chapter 4 outlines the essential features of conflict, and juxtaposes them with Lazarus' appraisals that activate emotion. The main objective of this chapter is to support the postulate that emotion is an essential ingredient in conflict analysis. In Chapter 5, Damasio's somatic marker hypothesis is operationalized using the possibility principle by expanding the set of feasible states to include *hidden* and *potential* states. The US-North Korea conflict is used to illustrate this concept in a real-world case. Chapter 6 concentrates on formally defining a perceptual graph model and a graph model system and on designing algorithms to carry out stability analyses of this system. The standard solution concepts, which are introduced in Chapter 2, are extended to accommodate inconsistent perceptions. This is done with perceptual stability analysis, which takes into account each DM's awareness of the states in his or her perceived graph model that are not recognized by opponents. Subsequent to these theoretical developments, a real-world dispute is presented to illustrate how perceptual stability analysis is practically applied in analyzing a graph model system. Finally, Chapter 7 concludes the thesis with a summary of the original contributions and anticipated future research.

Chapter 2
The Graph Model for Conflict Resolution

2.1 Overview

By its nature, a model is an abstraction—a simplified yet well-defined representation, intended to capture key characteristics and relationships that are important to the issues at hand (Obeidi, Hipel, and Kilgour, 2006). Representation and simplification are often difficult to achieve simultaneously. Nonetheless, even the most abstract models can effectively describe the key components of a state of affairs, and provide concrete insights into behavior.

The Graph Model for Conflict Resolution (Fang, Hipel, and Kilgour, 1993) is a methodological approach for framing an interactive decision situation, or conflict, in a format to which stability analysis can be applied. It serves as a prospective or retrospective strategic assessment tool for disputes; it also serves as a simulation tool for DMs' interactions and behavior, and can be used in negotiation preparation and mediation.

The Graph Model, which originated in *conflict analysis* (Fraser and Hipel, 1984) and ultimately in *metagame theory* (Howard, 1971), employs definitions phrased in terminology from graph theory, set theory, and logic to model and analyze a conflict. Within its structure, the basic lens for analysis is the *state*, which permits the representation of a DM's available actions as the state-to-state transitions it controls. Each DM's possible moves from state to state are depicted using a directed graph in which nodes represent states and arcs indicate state transitions controlled by the DM. The model is considered to always be in some state; changes of states are controlled by the DMs. Thus, a state is a potential outcome, or scenario, of the conflict. Usually, a Graph Model specifies an initial state, or *status quo*.

The systematic procedure for applying the Graph Model follows the two main stages shown in Figure 2.1. In the modeling stage, the problem is structured by determining the key ingredients: the DMs, the states, the possible state transitions controlled by each DM, and each DM's relative preferences over the states. Next, in the analysis stage, the stability of each state from each DM's viewpoint is determined. The DMs' interactions are conceived as directing the evolution of the conflict from a *status quo* state via state transitions until some stable state is reached, representing a resolution of the conflict.

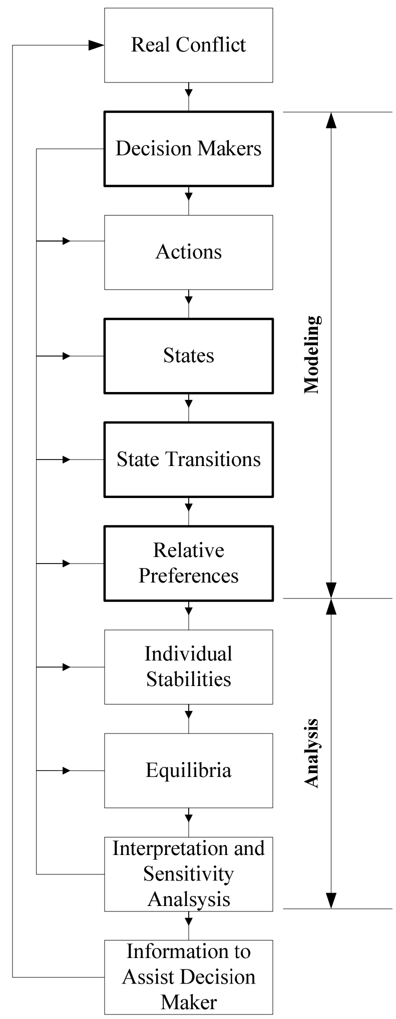


Figure 2.1: Applying the Graph Model for Conflict Resolution.

Uncertainty in DMs' preferences and sudden or unforeseen events that affect the robustness of stability analyses and the dynamics of the conflict are uncovered using sensitivity analysis. Like any model, the Graph Model is an abstract representation of key elements of a conflict. One can rarely be sure of the accuracy and completeness of the information used to calibrate a conflict model. Sensitivity analyses focus on the implications of changes in model parameters, by asking *what-if questions*, or studying how the preferences of a DM would have to be changed to produce more preferable equilibria for another DM. A reasonable range of possible preferences can be analyzed to ascertain how equilibria are affected. If the equilibria do not change as preferences are modified, one can have greater confidence in the results of the analysis. Alternatively, when the equilibria change drastically with small preference changes, then the analyst must ensure that the model is as accurate and reliable as possible.

2.2 Ingredients and Definitions of a Graph Model

The modeling stage in Figure 2.1 can be described using the flow diagram shown in Figure 2.2. It is often convenient to develop a graph model using the *option form* (Howard, 1971); this method, for example, is used in the decision support system GMCR II (Hipel, Kilgour, Fang, and Peng, 1997; Fang, Hipel, Kilgour, and Peng, 2003a,b).

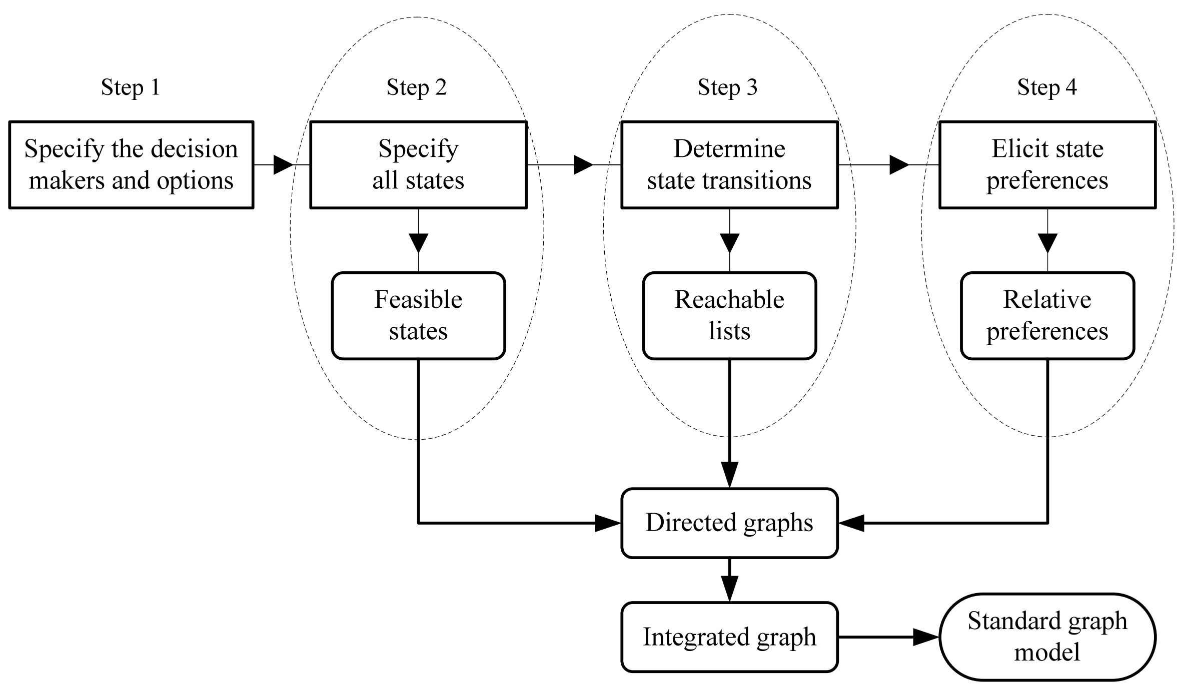


Figure 2.2: Flow diagram of the modeling stage in the Graph Model.

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

Often there are substantive, logical reasons why a particular combination of options does not represent a feasible state. If so, the combination is removed by specifying how options are contingent, co-requisite, obligatory, or mutually exclusive. An option is contingent if its availability depends on the selection of another option. For example, option A is contingent on option B when option A can be selected only if option B is selected. Contingent options are said to be co-requisite when they must be taken, or not, together; thus, option B is co-requisite for option A if A is taken when B is taken, and A is not taken when B is not taken. Options are obligatory if at least one of them must be taken, and mutually exclusive if at most one of them can be taken (Hipel, Kilgour, Fang, and Peng, 1997). Mutually exclusive options can be described simply as incompatible; for instance, either option A or option B can be chosen, possibly neither, but not both. A feasible state is a combination of options that does not violate any constraint: combinations that violate constraints are called “infeasible.”

State transitions are determined in Step 3 of Figure 2.2. The state-to-state transitions controlled by a DM are exactly those implied by a unilateral change of the DM’s option selection. These steps produce the usual set of directed graphs, and the graph model is completed in Step 4 by each DM’s relative preferences among feasible states. Since each

DM's graph has the same set of nodes, it is often useful to show all DMs' graphs on the same diagram by simply integrating them and labeling each arc to indicate the DM who controls it.

Such a graph is called the integrated graph of the model. A graphical representation of the information garnered in the modeling stage gives a convenient and clear structure for envisioning outcomes, any choice or transition restrictions, and possible moves and countermoves by the DMs. Often, strategic insights are gained from studying the graph, even before any stability analyses are carried out.

Formally, let N denote the set of all DMs, where $1 < |N| < \infty$. The set of states is S, where $2 \le |S| < \infty$. A graph model for a conflict consists of a collection of directed graphs. Each DM is said to have a directed graph in which the nodes are the states and the arcs are the state-to-state transitions controlled by the DM. For each $i \in N$, DM i's directed graph is written as (S, A_i), where DM i's arcs are $A_i \subset S \times S$. Another component of a Graph Model is each DM's relative preferences among states, which are usually expressed by pairwise comparisons of states, whereby a DM prefers one state more than another or is indifferent between them. Hence, for each $i \in N$, DM i's preferences over S are usually expressed by the binary relations $\{\succ_i, \sim_i\}$, where $a \succ_i b$ means that DM i strictly prefers a to b and $a \sim_i b$ means that DM i is indifferent between a and b. The Graph Model can handle both transitive and intransitive preferences. However, in most real life conflicts DMs' preferences can be assumed to be transitive, and thus expressed as a ranking (ordering) of the states from most to least preferred, where ties are allowed. (More discussion about the properties of these binary relationships is given later in Chapter 6, Section 6.2.)

Based on DM *i*'s preferences over states, S can be partitioned into two sets, relative to a particular or focal state $s \in S$, as follows: $\Phi_i^+(s) = \{s_m \in S : s_m \succ_i s\}$ is the set of all states that DM *i* prefers to state s; and $\Phi_i^{\leq}(s) = \{s_m \in S : s \succeq_i s_m\}$ is the set of all states that DM *i* finds equally or less preferred to state s. In the Graph Model, the set of all states that DM *i* can unilaterally reach from state $s \in S$ in one step is the *reachable list* $R_i(s)$. Hence, the concept of *unilateral improvement* is based on a DM's preferences and his or her reachable list. A unilateral improvement (UI) from a particular state for a specific DM is a preferred state (for that DM) to which he or she can unilaterally move in one step. It follows that $R_i(s)$ can be partitioned into two subsets: $R_i^+(s) = R_i(s) \cap \Phi_i^+(s)$ is the set of *unilateral improvements* from state s for DM *i*; and $R_i^{\leq}(s) = R_i(s) \cap \Phi_i^{\leq}(s)$ is the set of *unilateral disimprovements* from state s for DM *i*.

2.3 Stability Analysis

The stability of states for DMs is defined by various solution concepts, or stability definitions, which are mathematical descriptions of patterns of reasoning that formally model social behavior capturing a wide range of decision styles in conflict situations. Table 2.1 lists the solution concepts that are commonly used for assessing stability of states and equilibria, along with a qualitative description of how each solution concept is designed to reflect human behavior under conflict. These solution concepts encompass diverse decision styles and behavioral patterns from cautious and conservative to strategic and proactive and from naïve to sophisticated.

Table 2.1: Solution Concepts in the Graph Model and their Behavioral Interpretations

Solution Concepts	Stability Descriptions	Characteristics			
		Foresight	Disimprovement	Knowledge of Preferences	Strategic Risk
Nash Stability	A focal DM cannot unilaterally move to a more preferred state.	Low	Never	Own	Ignores risk.
General Metrationality	All of the focal DM's unilateral improvements are sanctioned by subsequent unilateral moves by others.	Medium	By Opponent	Own	Avoids risk; conservative
Symmetric Metarationality	All focal DM's unilateral improvements are still sanctioned even after possible responses by the focal DM.	Medium	By Opponent	Own	Avoids risks; conservative.
Sequential Stability	All of the focal DM's unilateral improvements are sanctioned by subsequent unilateral improvements by others.	Medium	Never	All	Takes some risks; strategizes.
Limited-move Stability (L_h)	All DMs are assumed to act optimally and a maximum number of state transitions (h) is specified.	Variable	Strategic	All	Accepts risk; strategizes.
Non-myopic Stability	Limiting case of limited move stability as the maximum number of state transitions increases to infinity.	High	Strategic	All	Accepts risk; strategizes.

The characteristic called foresight refers to the DM's ability to consider possible future moves. Nash stability (Nash, 1950, 1951) reflects a DM who thinks only one step ahead. In general metarationality (GMR) (Howard, 1971) and sequential stability (SEQ) (Fraser and Hipel, 1984), a DM considers exactly two steps ahead; whereas in symmetric metarationality (SMR) (Howard, 1971), the DM contemplates three steps by assessing available escapes from any sanctions that may be imposed by the opponents. Limited-move stability (Fang, Hipel, and Kilgour, 1993; Kilgour, 1985; Zagare, 1984) allows a DM a foresight of horizon h moves distant (referred to as L_h stability); whereas in non-myopic stability (Brams and Wittman, 1981) foresight is unlimited.

Disimprovement refers to the tendency of a DM to move to a less preferred state in order to reach a more preferred state eventually, or to block unilateral improvements of other DMs. In limited-move and non-myopic stability, a DM may accept a strategic disimprovement. But in Nash and sequential stability, disimprovements are never permitted, while in general and symmetric metarationality only disimprovements by the opponents for the purpose of sanctioning are allowed.

The knowledge of preferences refers to the amount of information available to a DM about its own and the others' relative preferences over states. Under Nash, GMR, and SMR stability, opponents' preferences are not needed. But under SEQ, limited-move, and non-myopic stability, knowledge of opponents' relative preferences among states is required.

The characteristic called strategic risk refers to the attitude of a DM to risk. Nash stability refers to a myopic DM who ignores risk. In GMR and SMR stability, the DM is conservative and exhibits a risk-averse decision attitude, while in SEQ, limited-move, and non-myopic stability, the DM gradually accepts some risk.

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

However, in limited-move and non-myopic solution concepts, DMs' preferences must be transitive. Behavioral game theorists have challenged recently the notion of unlimited strategizing, arguing that in an interactive decision situation DMs are often capable of thinking only a limited numbers of steps ahead (Camerer, 2003; Johnson, Camerer, Sen, and Rymon, 2002; Costa-Gomes, Crawford, and Broseta, 2001). Following this view, limited-move and non-myopic stabilities may not provide as many practical insights as the other solution concepts, and will not be emphasized in this thesis.

2.4 Formal Definitions of Standard Solution Concepts

A state is considered to be stable for a DM if and only if (iff) that DM is not tempted to move away from it unilaterally. A state is an equilibrium, or a possible resolution under a particular solution concept, if all DMs find it to be stable under that solution concept. In the following, Nash stability, general and symmetric metarationality, and sequential stability are defined for two-decision maker conflicts modeled in graph form. For simplicity, let $N = \{1,2\}$ and either $i = 1$ and $j = 2$ or $i = 2$ and $j = 1$. Furthermore, assume that DM *i* seizes the initiative and moves first. Hence, i is called the focal DM and DM *j* is *i*'s opponent.

Definition 2.1: Nash stability

For $i \in N$, a state $s \in S$ is Nash stable for DM *i*, denoted by $s \in S^{\text{Nash}_i}$, iff $R_i^+(s) = \varnothing$.

Under the Nash solution concept, a DM will move to a more preferred state whenever possible, without regard to any possible countermoves by the opponent. Hence, a state s is Nash stable for DM *i* iff *i* has no unilateral improvements from s.

Definition 2.2: General metarationality (GMR)

For $i \in N$, a state $s \in S$ is general metarational stable for DM *i*, denoted by $s \in S^{\text{GMR}_i}$, iff for every $t \in R_i^+(s)$ there exists $R_j(t) \cap \Phi_i^{\leq}(s) \neq \varnothing$.

Thus, a state s is general metarational stable for DM i iff for every UI *i* can take advantage of, the opponent, DM *j*, can subsequently move to a state that is at most as good for *i* as the original state s. In other words, DM *j* can *sanction* each of *i*'s UIs by moving to a state that is less than or equally preferred to state s by DM i. Therefore, a DM who follows general metarationality selects his or her unilateral moves in light of the opponent's possible reactions, irrespective of the opponent's preferences.

Definition 2.3: Sequential stability (SEQ)

For $i \in N$, a state $s \in S$ is sequentially stable for DM i, denoted by $s \in S^{\text{SEQ}_i}$, iff for every $t \in R_i^+(s)$ there exists $R_j^+(t) \cap \Phi_i^{\leq}(s) \neq \varnothing$.

A state s is sequentially stable for DM i iff every UI for i from s is *credibly sanctioned* by the sanctioner DM j. A credible sanction is a sanction that directly benefits the sanctioner, i.e., is also a UI for the sanctioner. A DM who follows sequential stability takes into consideration not only his or her possible moves, but also the opponent's unilateral improvements.

Definition 2.4: Symmetric metarationality (SMR)

For $i \in N$, a state $s \in S$ is symmetric metarational stable for DM i, denoted by $s \in S^{\text{SMR}_i}$, iff for every $t \in R_i^+(s)$, $R_j(t) \cap \Phi_i^{\leq}(s) \neq \varnothing$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s)$, $R_i(h) \cap \Phi_i^+(s) = \varnothing$.

A state s is symmetric metarational stable for DM i iff not only every UI for i from s is sanctioned by the opponent, but no unilateral counter-response by DM i can leave it better off than the original state s. In other words, there is an inescapable sanction to every possible UI by DM i.

The flow chart diagram in Figure 2.2 depicts the determination of whether a state s is Nash, GMR, SMR, and SEQ stable from the point of view of DM *i* for the general case of n decision makers. State s is Nash stable for DM i if i cannot move away from s to any state *i* prefers. Such a move would be called a unilateral improvement (UI) for DM *i* from state s. The (myopic) underlying assumption of Nash stability is that DM *i* expects that the other DMs, $|N - i|$, would not move away from the state reached after i's move. A state s is GMR stable for DM i iff for every UI available to *i* there is at least one state t that DMs $|N - i|$ can reach through a combination of subsequent moves, such that state *t* is at most equally preferred to state s for DM *i*. Thus, under GMR stability, DM *i* assumes other DMs will respond to *i*'s move by sanctioning *i*, i.e. by hurting *i* if it is possible for them to do so, regardless of their own preferences. The SEQ solution concept is similar to GMR except that the sanction by DMs $|N - i|$ must be credible, i.e. it must consist only of unilateral moves that are UIs for the DMs who make them. If s is GMR stable for DM *i*, and DM *i* is incapable of counterresponding to every sanction of each UI available to *i*, then state s is also SMR stable for DM *i*. Note that under Nash the DM contemplates one move ahead, under GMR and SEQ two moves (or more if required to sanction), and under SMR three moves (again, more if the sanction requires it).

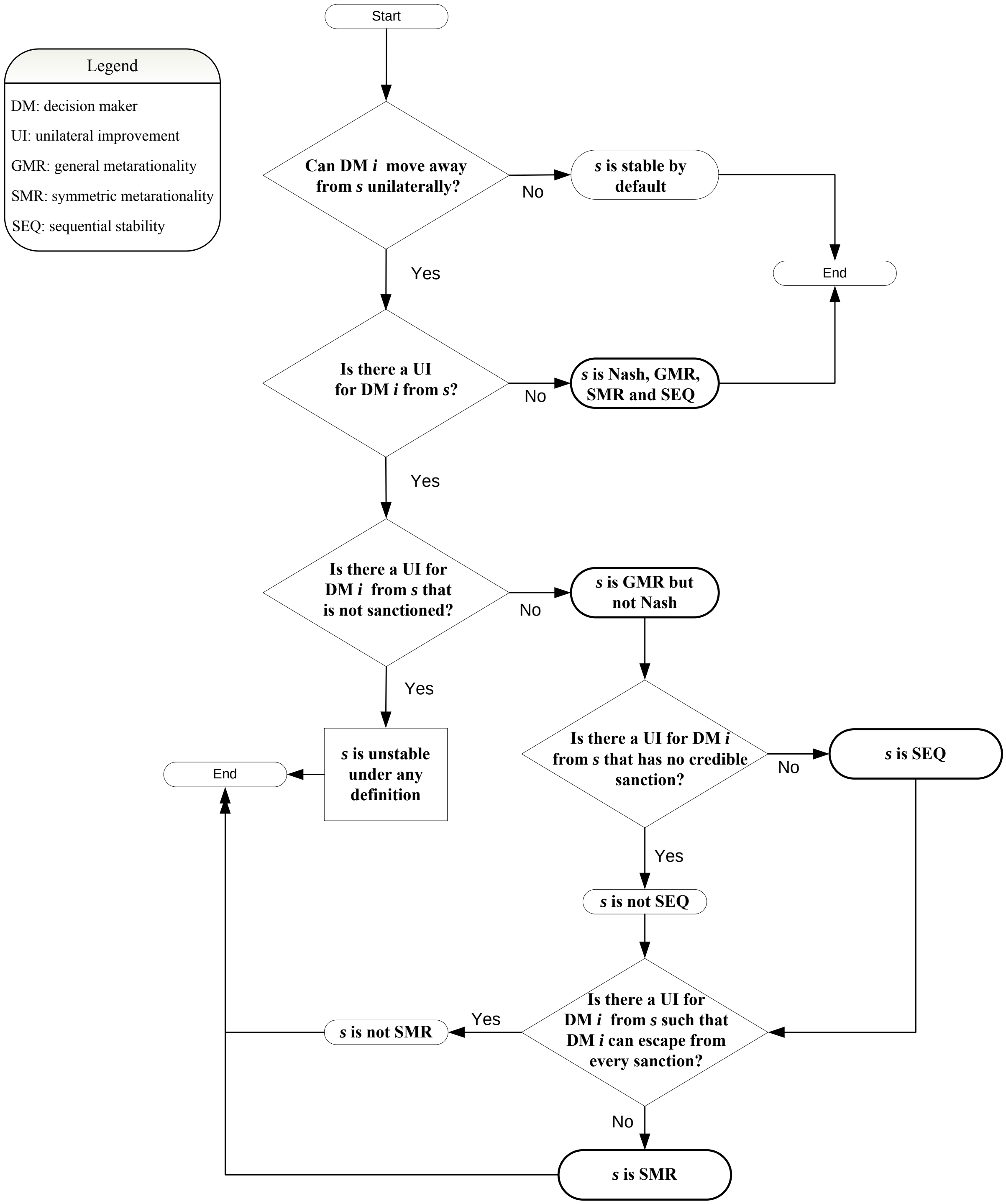


Figure 2.3: Stability analysis flow chart for Nash, GMR, SEQ, and SMR.

2.5 Summary

This chapter provides an overview of the Graph Model for Conflict Resolution. The systematic procedures for applying the Graph Model, including the option form platform that is used in the decision support system GMCR II, are explained. Definitions of the solution concepts used in the Graph Model to capture various decision styles, and their characteristics, are furnished. Finally, a flow chart diagram illustrates how stability analysis is applied for the Graph Model solution concepts Nash, GMR, SEQ, and SMR. In the next chapter, some definitions of emotion are given, and then succinct descriptions are provided of: (1) brain structures involved in processing and activating emotions, and (2) Damasio's somatic marker hypothesis.

Chapter 3
Emotion

3.1 Definitions of Emotion

Today, there is no commensurable definition for emotion that is acceptable to all scholars across different fields of study (Plutchik, 1980, 2002). Traditionally, emotions were considered “bodily changes follow directly the perception of the exciting fact” (James, 1884, p. 204), “hereditary *pattern-reaction* involving changes of the bodily mechanisms as a whole” (Watson, 1924, p. 22), or biological functions necessary for survival (Maclean, 1963).

Nowadays, some scholars view emotions as psychological response patterns and subjective experiences (Lazarus, 1991), “tendencies to establish, maintain, or disrupt relationship with the environment” (Frijda, 1986, p. 71), “*valenced* reactions to events” (Ortony, Clore, and Collins, 1988, p. 25), or “experiential representation of a nonsymbolic information-processing system" (Jones, 1995, p. 201). Naturally, researchers across different fields of study propose a variety of definitions in which some emphasize certain aspects of emotion, such as its nature, characteristics, and functionality, and some focus on what causes the phenomenon and how it is expressed.

Many social scientists, for example, advocate a *constructionist* view of emotion, in which they contend that although some basic (or primary) emotions such as fear, anger, happiness, sadness, and disgust are biologically hardwired in the brain, complex emotions, which are vital to social integration, are learned and frequently adapted under the influence of norms, values, and beliefs of a specific culture (Averill, 1980; Cornelius, 1996; Turner and Sets, 2005). According to Averill (1980, p. 309), "Emotions are not just remnants of our phylogenetic past, nor can they be explained in strictly physiological terms. Rather, they are social constructions, and they can be *fully* understood only on a social level of analysis."

On the other hand, affective neuroscientists such as LeDoux, Damasio, and Panksepp focus on the adaptive, integrative functions of emotion that underlie vital cognitive processes such as memory, perception, and attention (Adolphs, 2003a; Dolan, 2002). Adolphs (2003a), Damasio (1994), Frijda, Mansted, and Bem (2000), LeDoux (1986, 1996), and Scherer (2001), among others, view emotion as mental states of arousal that arises in reaction to exteroceptive (body's exterior) or interoceptive (body's interior) sensory stimuli. An *arousal state* represents varied patterns of ongoing activities and processes in all brain areas, which produces different internal and external responses, and intends to regulate life processes and promote survival (Damasio, 2003). These responses, for instance, can be autonomic (e.g., a change in heart rate, rapid breathing, blood pressure), endocrine (hormone releases), behavioral, motivational, and expressive (e.g., facial expressions, body posture) changes, which are functions of emotion in reaction to a stimulus of concern (Rolls, 1999). Panksepp (1998, p. 48) views emotions as "the psychoneural processes that are especially influential in controlling the vigor and patterning of actions in the dynamic flow of intense behavioral interchanges between animals, as well as with certain objects during circumstances that are especially important for survival."

Experimental psychologists focus on the subjective or experiential aspects of emotion that emphasize excitement/depression or pleasure/displeasure. Rolls (2000, p. 178), for example, defines emotions as "states elicited by rewards and punishments, including changes in rewards and punishments."

Some scholars attribute the challenge in defining emotion to the complexity of the states and processes associated with it. Young (1973, p. 749), for instance, argues that "almost everyone except the psychologist knows what an emotion is….The trouble with the psychologist is that emotional processes and states are complex and can be analyzed from so many points of view that a complete picture is virtually impossible." Kleinginna and Kleinginna (1981, p. 355) conclude that a definition of emotion should be "broad enough to include all traditionally significant aspects of emotions, while attempting to differentiate it [emotion] from other psychological processes." They compiled, analyzed, and classified a list of ninety two definitions of emotion, which they gathered from a variety of literature on the subject, and proposed the following definition: "Emotion is a complex set of interactions among subjective and objective factors, mediated by neural/hormonal systems, which can (a) give rise to affective experiences such as feelings of arousal, pleasure/displeasure; (b) generate cognitive processes such as emotionally relevant perceptual effects, appraisals, labeling processes; (c) activate widespread physiological adjustments to the arousing conditions; and (d) lead to behavior that is often, but not always, expressive, goal-directed, and adaptive" (Kleinginna and Kleinginna, 1981, p. 355).

3.2 The Neurobiological Underpinnings of Emotion

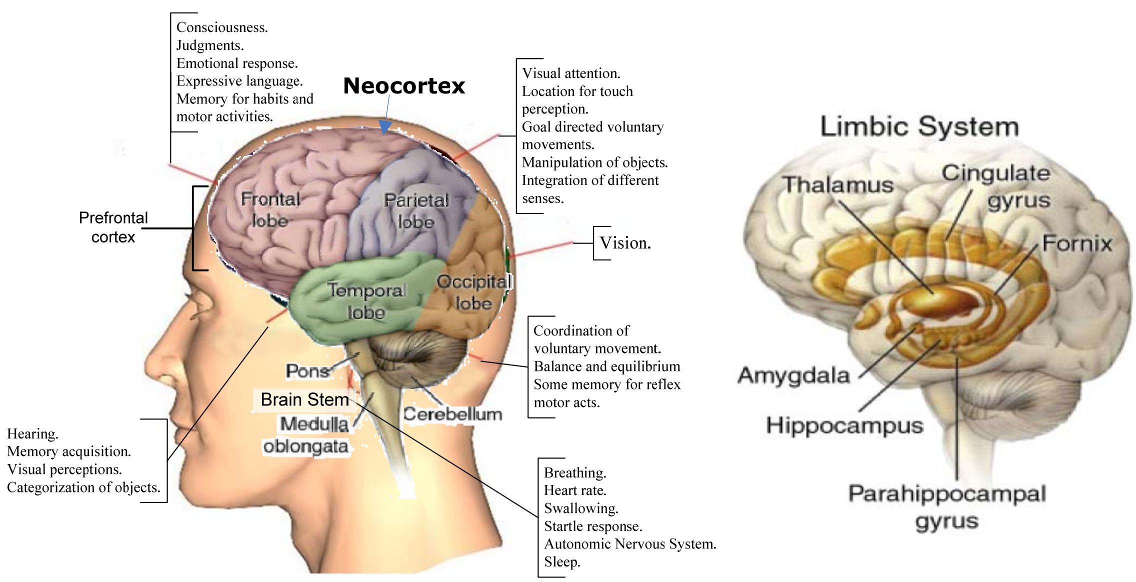
For decades, philosophers, psychologists, and neuroscientists have been studying the nature of emotion. The earliest views were those of the Ancient Greek philosophers such as Plato (427-347 BC) and Aristotle (384-322 BC). Aristotle, for example, recognized the importance of using emotion in reasoning and persuasion. In *Rhetoric*, Aristotle reflected that emotion requires three prerequisites to be activated: proper state of mind, stimulus, and context (Power and Dalgleish, 1997). In the 19th century, the exceptional naturalist Charles Darwin (1809-1892) suggested that emotion is an evolutionary phenomenon that has a very important survival function in all animals (Darwin, 1873). Well-known Darwinians, such as William McDougall, Robert Plutchik, Paul Ekman, Carroll Izard, and Sylvan Tompkins, are still focusing their research on the universal (i.e., basic) emotions: what causes them and how they are expressed. Shortly after Darwin came up with his opinion about emotion, William James (1842-1910), a psychologist and philosopher, insisted that the common view to think about how emotion is felt is not correct. James (1884) suggested the first theory of emotion activation, in which he contended that bodily changes (e.g., increased heart rate and muscles tension) directly follow the perception of an event, and that the feeling of these bodily changes is the emotion. At the time, a physician and psychologist, Carl Lang (1834-1900), supported James' view. However, the James-Lang theory of emotion was refuted by a student of James, Walter Cannon (1871-1945). Cannon, a physiologist, raised questions about the James-Lang theory, and argued that it was flawed (Cannon, 1945). Ironically, some modern neuroscientists partially agree with the James-Lang theory (Damasio, 2003; Dolan, 2002).

Afterward, the dynamic relationships between cognitive and emotional processes have been the focus of many psychologists and neuroscientists. Stanley Schachter's two-factor theory, which described, for the first time, the presence of a cognitive component in the process of experiencing emotion, was eventually replaced by an appraisal theory (explained in Section 3.2.2 from a neurological point of view, and also described in Chapter 4, Section 4.2), of which many scholars in the field (e.g., Magda Arnold, Richard Lazarus, Nico Frijda, Ira Roseman) fully support.

Advances in neuroimaging technologies, especially functional magnetic resonance imaging (or fMRI), have facilitated the study of the neurobiological substrates of emotion (Adolphs, 2003a; Dolan, 2002). Researchers now have a better understanding of the central role of emotion (mediation, regulation, or coordination) in memory, learning, and attention (Adolphs, 2003a,b; Dolan, 2002); and of the association between cognitive and emotional processes in various brain regions (Houser, Bechara, Keane, McCabe, and Smith, 2005; Damasio, Grabowski, Frank, Galaburda, and Damasio, 1994). Some study the neural underpinnings of emotion (e.g., Joseph LeDoux), and others investigate the structural underpinnings of emotion (e.g., Antonio Damasio and Antoine Bechara). The following is a brief description of brain structures that are mainly responsible for processing and activating emotion. (Much of the information in the following section is drawn heavily from Noback, Strominger, Demarest, and Ruggiero (2005) and Gazzaniga, Ivry, and Mangun (2002).)

3.2.1 The Central Nervous System

The nervous system is composed of the central nervous system, which includes the brain and the spinal cord, and the peripheral nervous system. The peripheral nervous system consists of the somatic system, where electrochemical impulses travel between the brain and the muscles via nerve fibers, and the autonomic nervous system, which consists of nerve fibers that carry electrochemical impulses between the brain and the viscera (singular is viscus)—the internal organs, especially those contained in the abdominal and thoracic cavities. The autonomic nervous system maintains the internal body in a state of balance, i.e., *homeostasis* (Cornelius, 1996).



(Adapted from http://www.ahaf.org/alzdis/about/AnatomyBrain.htm)

Figure 3.1: The cerebral cortex (left) and the limbic system (right).

In the left diagram of Figure 3.1, the cerebral cortex (or brain) is mapped out in terms of five main lobes, in which each is symmetrically located in the cerebral hemispheres. The temporal lobe is located on the side, beneath and behind the ear, and is involved in the sensing of smell and sound, as well as processing of complex stimuli like faces and scenes. The occipital lobe is located at the far back of the brain, and mainly connected to the eyes. The parietal lobe is located above the temporal lobe and in front of the occipital lobe, and plays important roles in integrating sensory information from various senses, and in the manipulation of objects; portions of the parietal lobe are involved with visuo-spatial processing. The frontal lobe is located at the front of each cerebral hemisphere, where the temporal lobes are located beneath and behind the frontal lobes. The frontal lobes are involved in motor function, problem solving, spontaneity, memory, language, initiation, judgment, impulse control, and social and sexual behavior (Adolphs 2003a; Wood and Grafman, 2003).

The anterior part of the frontal lobe is the prefrontal cortex (PFC), which is a hub for a high number of interconnections with other brain regions, especially deeper structures such as the limbic system. The prefrontal lobe can be divided into ventromedial, dorsolateral, and orbitofrontal regions. According to Wood and Grafman (2003), the ventromedial PFC is closely associated with brain structures responsible for processing emotion (e.g., amygdala), memory (i.e., hippocampus), higher-order sensory processing, and relaying information to the dorsolateal PFC. Lesions to the ventromedial PFC impair the ability to experience emotion and comprehend meaning of things (Damasio, 1994; Wood and Grafman, 2003). On the other hand, the dorsolateral PFC is associated with brain structures responsible for motor control (e.g., basal ganglia, premotor cortex), performance monitoring (e.g., cingulated cortex), and higher-order sensory processing. Therefore, the dorsolateral PFC supports regulation of behavior, control responses, and the representation of cognitive actions (Wood and Grafman, 2003). The orbitofrontal cortex has been associated with social reasoning, social and moral judgment (i.e., right or wrong choices), and long terms strategic gains (Adolphs, 2003a).

Different regions in the brain are responsible for the evaluation of stimuli that are of concern (i.e., emotion-inducing stimuli) and in the experience and expression of emotion (Cornelius, 1996). The most important areas are the limbic system and various areas in the cerebral cortex. As shown in Figure 3.1 (right), the limbic system is a complex interconnection of neural structures bordering the thalamus, and includes the amygdala, the hypothalamus, the hippocampus, the cingulated cortices, and several other nearby areas, especially the limbic forebrain (ventromedial PFC). The limbic system appears to be primarily responsible for processing emotional states, and has a lot to do with the formation, mediation, and regulation of memories (LaBar and Cabeza, 2006).

The amygdala is the most important neural structure that has been shown to be responsible for post-perception processing of information projected from the sensory thalamus and higher-order sensory cortices (Adolphs, 2003a,b; Emery and Amaral, 2000; LeDoux, 1996, 2000). The amygdaloid complex is an almond-shaped mass of grey matter, which is anatomically located in the anterior portion of the temporal lobe and composed of a number of nuclei. Several brain components relay information to the amygdala.

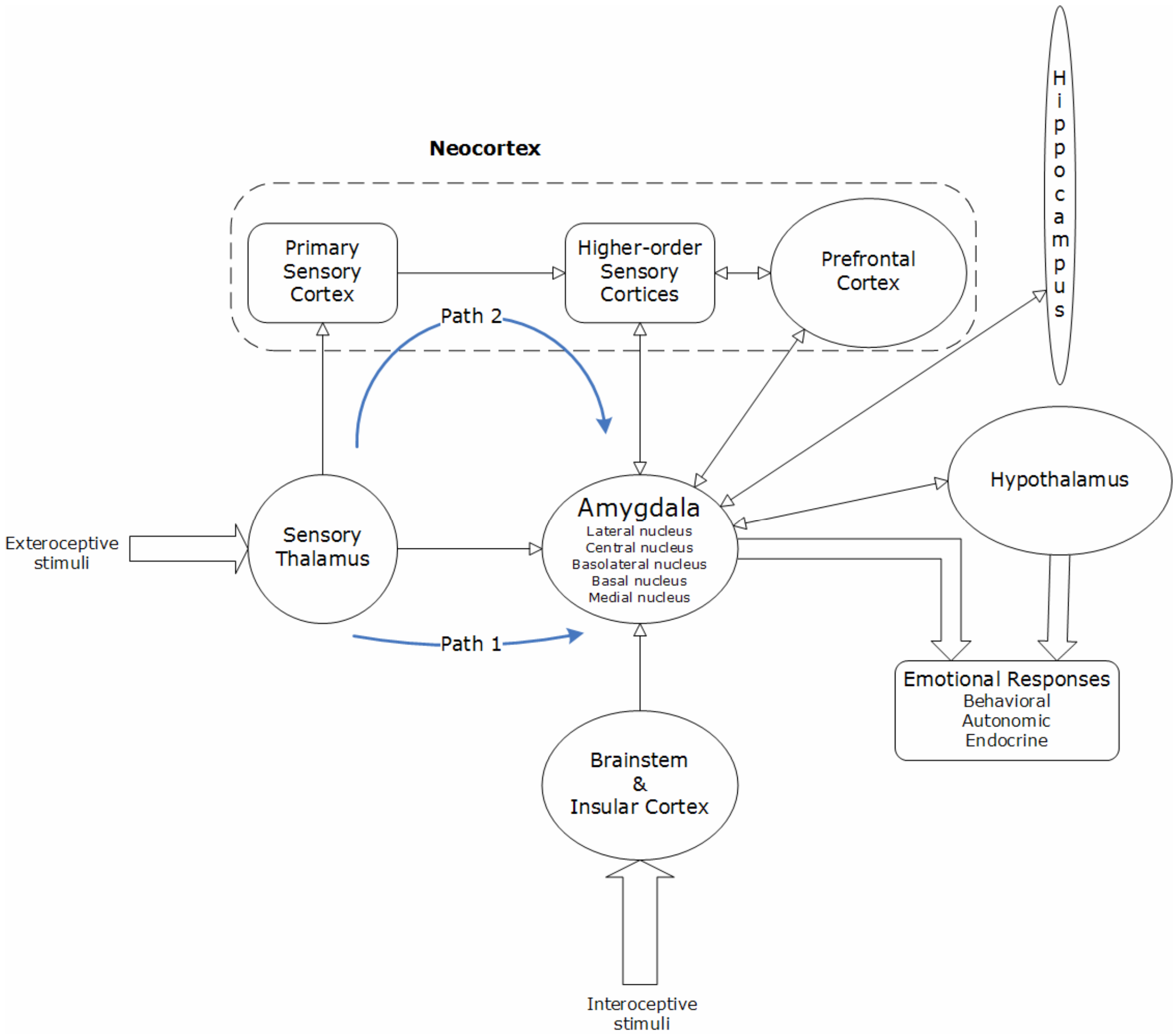


Figure 3.2: Amygdala connection and pathways (Adapted from LeDoux, 2000).

As shown in Figure 3.2, the sensory thalamus detects exteroceptive stimulus (auditory or visual) and projects it to the amygdala; brainstem and insular cortex also project interoceptive stimulus (visceral or somatic such as touch, pressure, temperature, and pain) to the amygdala. The amygdala, then, assigns affective values (emotions), stores codes for subsequent processing of such perceptual information, and projects signals to various structures such as the prefrontal cortex and the hippocampus, which is involved in storing and retrieving memory and in the processing of a set of stimuli to create context to a situation (Adolphs, 2003b). The amygdala, therefore, influences memory, attention, decision making, and other cognitive processes, and activates emotional states to stimuli, which are manifested in the form of behavioral, autonomic (heart rate, blood pressure), and endocrine (releases of hormones and neurotransmitters) responses. The amygdala can also modulate early perception of stimuli via direct feedback to primary and higher-order sensory cortices (Adolphs, 2003b).

Joseph LeDoux, a professor of neuroscience and psychology at New York University who focuses on the biological substrates of emotion, especially fear conditioning in rats (i.e., Pavlovian conditioning), theorized the presence of a dual-pathway for sensory information processing, which is involved in the activation of fear. According to LeDoux (1996, 2000), simple sensory information is relayed via the thalamus-amygdala pathway (a subcortical pathway), Path 1 in Figure 3.2. This pathway automatically mediates rapid, primary emotional responses, which provides initial defense intervention and early warning essential for survival. Subsequently, the amygdala begins regulating information projected from the higher-order and prefrontal cortices. The regulation can be direct, which is manifested by inhibition of stimuli (perceptual defense) and focusing attention on stimuli; or indirect by influencing other structures, such as the basal forebrain, which affects the cortical processing of stimuli. Complex sensory information is relayed through the thalamus-cortico-amygdala pathway, Path 2 in Figure 3.2, in which highly processed information in the neocortex is projected to the amygdala. This pathway may either signal to the amygdala to abort the defensive reaction or trigger further complex reactions. LeDoux (1996) suggests that information projected from the amygdala back to the higher-order and prefrontal cortices may influence and regulate the processing mechanisms in those areas.

3.2.2 Damasio's Somatic Marker Hypothesis

Antonio Damasio is a physician and neurologist, who along with his colleagues noticed that patients with lesions in areas located in the prefrontal cortex maintain normal levels of their cognitive capacities (memory, reasoning, speech) and intellects (Bechara and Damasio, 2005); but the same patients suffer from impairment in their faculties of making risky choices, especially in social contexts (Damasio, Grabowski, Frank, Galaburda, and Damasio, 1994). In particular, if the lesion is in the ventromedial PFC, the patients often become insensitive to future consequences, and they repeatedly make decisions that are obviously contrary to their best interests (Adolphs, 2003; Bechara, Tranel, and Damasio, 2000; Houser, Bechara, Keane, McCabe, and Smith, 2005). Furthermore, the patients show compromised abilities to express the proper emotions and experience feelings of these emotions (Bechara and Damasio, 2005).

Bechara and Damasio (2005, p. 339) define emotion as "changes in body and brain states triggered by a dedicated brain system that responds to specific contents of one's perceptions, actual or recalled, relative to a particular object or event." The bodily (i.e., *somatic*) changes are a collection of homeostatic processes, which aim at coping and life-regulation to promote survival and health (Damsio, 2003). Examples of these homeostatic processes may be the release of chemical (e.g., endocrine or hormonal secretions) and movement of mechanical (i.e, muscular contractions) components; changes in basic reflexes, immune system, behavior, drives, and motivation; and the activation of emotion and feeling.

Damasio and his colleagues suggest that emotion is triggered by an appraisal of an emotion-inducing stimulus. Appraisal can be primary and spontaneous, which activates basic emotions such as fear, anger, and sadness, or secondary and deliberate, which activates complex, social emotions such as shame, guilt, envy, and sympathy (Bechara and Damasio, 2005; Damasio, 1994). Figure 3.3 illustrates the mechanism of primary appraisal for the emotion of fear as described by Damasio (2003), where boxes on the left (shadowed) indicate the stage of appraisal process and boxes on the right identify brain structures mostly involved in processing the stage.

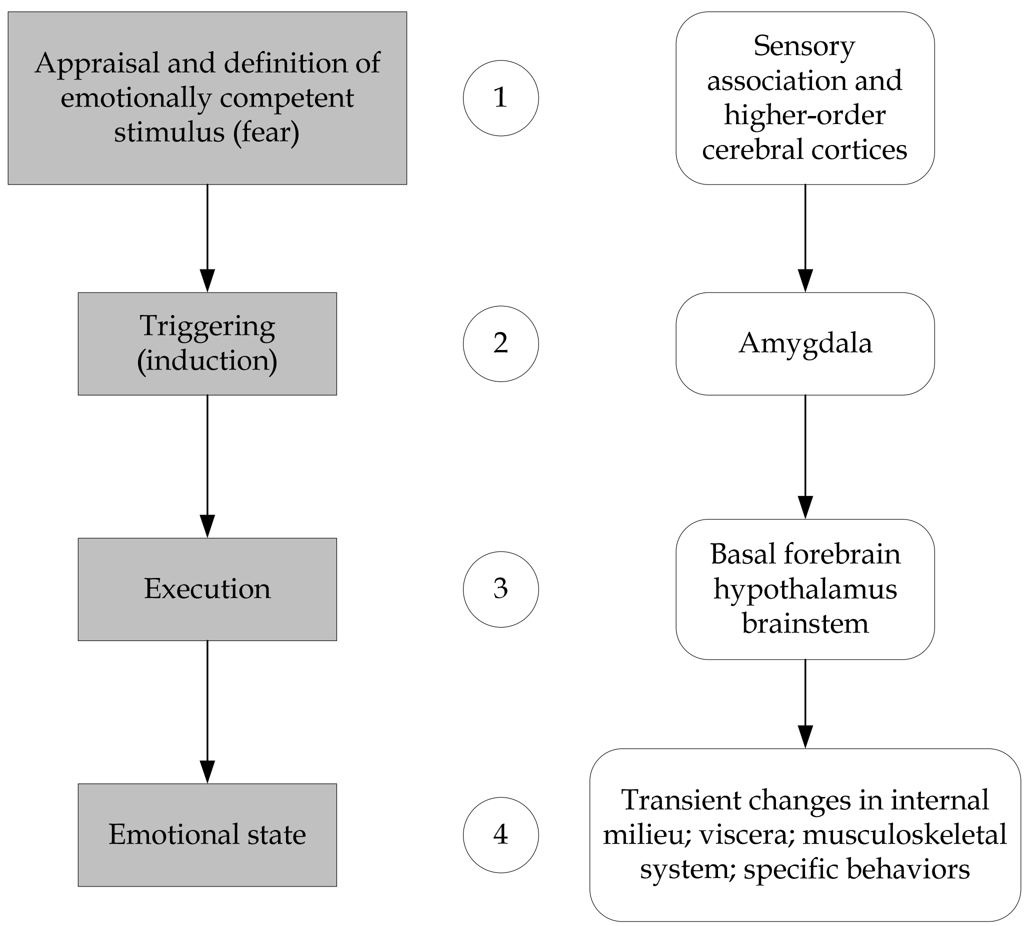


Figure 3.3: Appraisal of the emotion of fear (Damasio, 2003).

An emotion-inducing stimulus, which can be real, perceived, or recalled from memory, becomes available in some sensory cortices such as the thalamus or higher-order sensory cortices. The sensory cortices process the information and relay it to a number of brain structures that trigger emotions (i.e., emotion-triggering structures). As discussed in the previous section, the amygdala, cingulated cortex, and ventromedial PFC are some of the important sites in the brain that trigger emotional states. Here, it is the amygdala that triggers the emotion of fear (LeDoux, 2000). Subsequently, the emotion-triggering structures signal other sites (emotion-execution structures) to activate responses (i.e., *somatic states*) in the body proper and the brain, which correspond to the emotion of fear. Some of the emotion-execution structures are the hypothalamus, the basal forebrain, and some nuclei in brainstem. These responses can be in the internal milieu (fluids in the bloodstream and in the spaces between cells), in the function of the viscera and the central nervous system, and in the musculoskeletal system.

Damasio (1994, 2003) makes a clear distinction between an emotional state and a feeling state. In his view, emotions precede feelings, where the former are innate regulations that are essential for survival while the latter are higher-order experiences of these regulations and other somatic states. Dolan (2002, p. 1193) defines feelings as "mental representations of physiological changes that characterize and are consequent upon processing emotion-eliciting objects or states." Bechara and Damasio (2005) and Damasio (1994, 2003) view feelings as conscious and adaptive mental representations (i.e., neural mappings) in the form of perceptions of certain bodily responses, thoughts, experiences, or acquired knowledge, which arise from emotions and any homeostatic reactions. For instances, feelings of pleasure and sorrow are experiences of the emotions of joy and sadness, respectively, whereas feeling of appetite is the experience of distinctive somatic states: drive and motivation. According to Damasio (2003) and Dolan (2002), among others, the feelings of emotion become active when internal somatic sensory signals are projected from the viscera, the internal milieu, and the musculoskeletal system to structures in the limbic system, including the hypothalamus, brainstem, cingulated cortex, and to some areas in the somatosensory cortices, especially the insular—believed to produce an emotion-relevant context for sensory experiences. Upon experiencing these somatic states at least once, neural patterns of the feelings are marked and become distinctively associated with the emotion-inducing event.

A record of the activities in various regions such as sensory cortices and limbic system are held in the ventromedial PFC. When similar emotion-inducing events are subsequently encountered, the ventromedial PFC triggers the same feelings as the somatic states. These activated feelings and the accompanying somatic states influence activities in emotion-triggering structures that generate somatic states; regions that hold patterns of somatic states, i.e., generate feelings; regions involved in working memory, i.e., dorsolateral PFC regions (Rypma, Berger, and D'Esposito, 2002) and other higher-order cortices; and regions concerned with behavioral and motor response (Bechara and Damasio, 2005). Figure 3.4 illustrates the mechanism of which somatic states affect decision making as proposed by Damasio (1994, 2003). Path A projects facts related to the choice problem, i.e., emotional-inducing event, which include courses of action, anticipated consequences, and circumstances. Reasoning strategies operate on that knowledge. However, a complementary Path B activates feelings of prior emotional experiences of similar choice problems. The recalled feelings, whether conscious or unconscious, influence the decision making process by forcing attention on future outcomes or by interfering with reasoning strategies. If the situation requires an immediate response, Path B may also lead to a decision directly. The exact influence of somatic markers depends on the individual and the encountered decision problem.

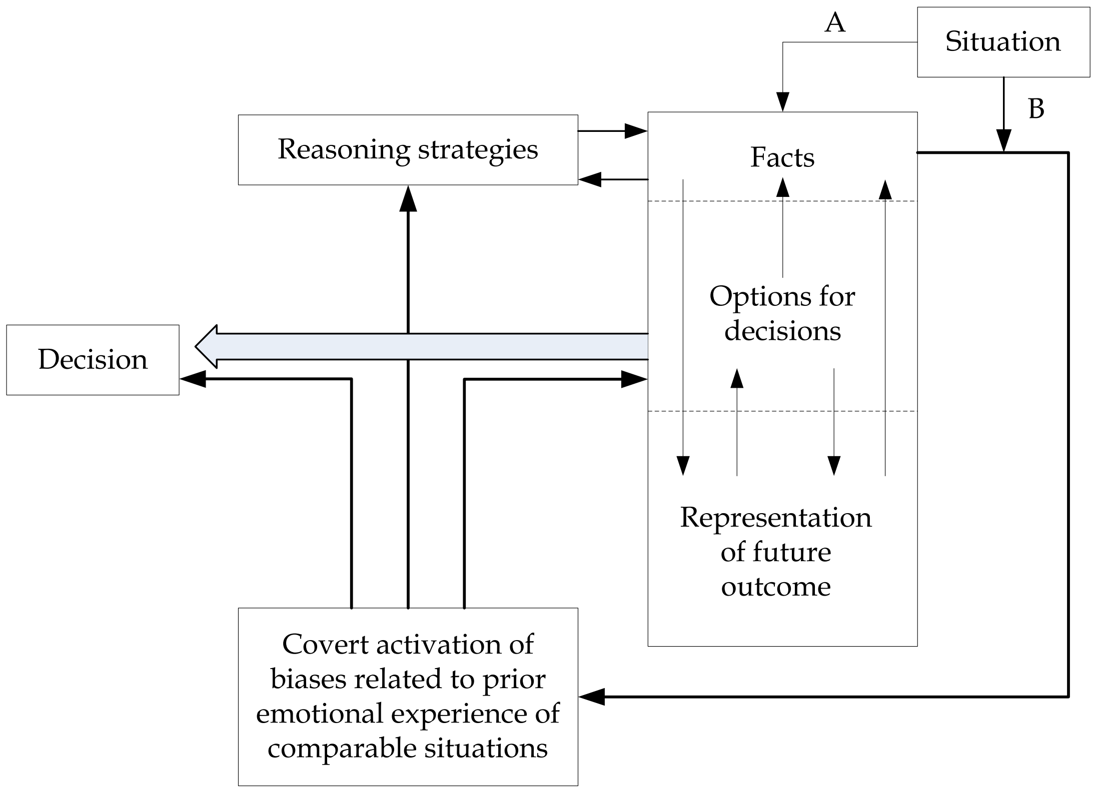


Figure 3.4: Schematic of the mechanism involved in making decision (Damasio, 2003).

3.3 Categorization and Valence of Emotions

In most psychological studies, emotions are categorized as either positive or negative (Frijda, 1986). For example, joy, love, and pride are considered positive emotions, while anger, sadness, fear, dislike, and frustration are negative emotions. Roseman (2001, p. 77) explains, "Positive emotions involve responses that get more of a stimulus, and negative emotions involve responses that get less of a stimulus." Therefore, this categorization assumes that the space of emotion is parsed according to two orthogonal dimensions: *arousal*, where emotion varies from calm to excitement, and *valence*, where emotion is assumed to be either pleasant (positive emotion) or unpleasant (negative emotion) (LaBar and Cobeza, 2006). Nonetheless, positively toned and negatively toned emotional states are interdependent and are not dichotomous (Lazarus, 2001a,b). For instance, anger is considered a negative emotion, which has no positive counterpart.

Moreover, often, emotions are not experienced discretely; rather a number of fundamental emotions combine to form complex emotional episodes (Izard, 1977; Lazarus, 2001a,b). For example, the emotion of *Schadenfreude*—i.e., malicious pleasure derived from the misfortune of negatively-valued others—is considered a complex emotion, of which some of its elements are joy and contempt (Roseman, Antoniou, and Jose, 1996).

The most important reason for analyzing emotions is for their functional responses. Several emotions have been considered in the study of conflict and social interactions. By and large, anger, fear, sadness, contempt, and shame are some of those germane emotions that have been recognized by mediation practitioners and sociologists (Barker, 2003; Jones and Bodtker, 2001; Kemper, 1987). For example, anger and fear are considered basic negative emotions, which are universal across cultures and often prevail in all social confrontation, albeit with varying intensities. On the other hand, moral emotions, such as guilt, shame, jealousy, pride, and embarrassment that are believed to develop within a social context, form a class that is vital in regulating human social behavior (Adolphs, 2003a,b). In this research, the focus will be on fundamental negative emotions that are likely to be present during conflict.

3.4 Summary

This chapter introduces the phenomenon of emotion. Various definitions for emotion from studies in psychology, sociology, neuroscience, and other disciplines are discussed. The neurobiological structures in the brain that process the exteroceptive and interoceptive sensory signals that activate emotion, and the accompanying homeostatic response, are briefly discussed. Finally, Damasio's somatic marker hypothesis and his hypotheses about of the mechanism of decisions making are explained. Damasio's beliefs about the effects of emotion on reasoning inspire the development of the possibility principle in Chapter 5. In the next chapter, various definitions for conflict are discussed. Then, to emphasize the significance of emotion in conflict modeling, features that characterize conflict are juxtaposed with appraisal theory for emotion activation.

Chapter 4
Emotion: The Missing Ingredient in Conflict Analysis

4.1 Characteristics of Conflict

One challenge facing researchers and practitioners in negotiation and conflict resolution is the detection of conflict. Some specialists view conflict as a competition of opposing forces, for example struggles over resources, ideas, values, wishes, and needs (e.g., Burton (1996), Porter and Taplin (1987)). Dispute settlement practitioners (including Alternative Dispute Resolution) consider conflict to be a consequence of clashes of opinions, needs, and wants (e.g., Tillett (1991)). Behaviorists and negotiation analysts see the defining characteristic of conflict as the perception of divergence of interests (Thompson, 1998) or incompatibility of goals (Carnevale and Pruitt, 1992). Rubin, Pruitt, and Kim (1994, p. 5) provide a more detailed characterization of conflict, based on "divergence of interest, or a belief that the parties' current aspirations cannot be achieved simultaneously."

Sandole (1998, p. 1) is even more comprehensive in his definition; he regards a conflict as a "situation in which at least two parties, or their representatives, try to pursue their *perceptions* of mutually incompatible goals by *undermining*, directly or indirectly, each other's goal-seeking capability." Others echo this view by portraying a conflict as an antagonistic social situation involving individuals who perceive incompatibility over issues such as goals, values, interests, or beliefs, and attempt either to control each other or to prevent others from attaining their aspirations (e.g., Fink (1986), Fisher (1990), Folger, Poole, and Stutman (1993)). (Various definitions and interpretations of conflict are provided by authors from a range of disciplines in a set of encyclopedia articles (Hipel, 2002).)

One difficulty in defining conflict lies in the incommensurability of terminology across fields of study. Does an expression of dissatisfaction, disagreement over an issue, or differences in opinion constitute a conflict (Costantino and Merchant, 1996; Geist, 1995)? For example, sometimes decision makers, who share common interests and goals, may find themselves in strong disagreement over resource allocation or policy making and implementation. Another example is differences in opinion between spouses over issues related to children's education; both parents want the best for their children, yet both may strongly oppose the other's ideas. In both examples, the differences in opinion may be in the set of criteria used to evaluate available information, differences due to subjective perceptions of the same issue, or differences in each party's personal construct (Kelly, 1955).

Various disciplines use the term *conflict* for different processes or events, reflecting their own underlying assumptions. Nonetheless, most agree that conflict is a ubiquitous and inevitable phenomenon that involves a relational dynamic (Eadie and Nelson, 2001). It is a *process rather than a situation or state of affairs*, commencing with an instigating event that establishes issues, and then evolving through different stages. The early stages are marked by emotional responses, which mediate action-readiness, while strategic choices preponderate in later stages, with correlation between earlier and later stages. Certainly, decision making is an important element in this process, especially in later stages where individuals begin formalizing their possible choices and preferences over possible outcomes. In this process, emotions and the associated action-readiness have a profound affect on the shaping of preferences and decisions. This conceptualization is useful in keeping us away from preoccupation with the outcome of conflict. In other words, consideration of means must have the same priority as consideration of ends.

Although there are many definitions for conflict, there is near-consensus that it is a process marked by psychological and sociological components, apparent in three distinct and fundamental characteristics: the crucial influence of perception, incompatibility of something of relevance, and interference; the last two features were first identified by Hammer (2001). To initiate a conflict, it is not the physical and social realities of a situation that are important, but how at least one of the parties perceives them. Perception is an active, unconscious inference process for information recognition, gathering, and interpretation, influenced by personal experience, culture, social status, and power, which regulate the attention, disposition, and response accorded to any stimulus (Rock, 1997). Perception may have nothing to do with reality and different individuals may perceive the world differently. For instance, the military confrontation of 2003 between the United States and the then Iraqi regime was mainly because of the former's perception that the latter posed a grave threat to its National interests and securities.

An essential characteristic of conflict involves the perception of *incompatibility* of something of *relevance*, at least for one party. This "thing" could be different goals, interests, beliefs, aspirations, or some process or service—the term goal/need will be used as shorthand for incompatibility. The more important this "thing" is to individuals, the more complex and ingrained the conflict becomes, and the harder it is to resolve. The third characteristic of conflict is *interference*, which happens when at least one party is unable to attain its goals independently, when that achievement is or has been undermined by others, or when the cost associated in achieving these goals alone is very high. Interference refers to the property of interdependence and interrelatedness, usually present in social interactions. The more interference in the conflict, the more control the parties can exert on each other's choices, behavior, and goal/need satisfaction.

4.2 Appraisal Theory of Emotion Activation

4.2.1 Lazarus's Cognitive-Motivational-Relational Theory

Recent research in neurobiology and psychology has investigated the role of emotions in judgments, decision making, appraisal, and evaluation of options. It has been suggested that emotional and cognitive processes are highly interactive and have reciprocal causal relations (e.g., Cornelius (1996), Frijda, Manstead, and Bem (2000), Izard (1993), Lazarus and Lazarus (1994)). Hence, complex and integrative interactions of emotional, cognitive, biological, and social processes are necessary for human development (Cacioppo and Gardner, 1999).

Magda Arnold, in the early 1960s, debated the Darwinian (Darwin, 1873) and Jamesian (James, 1884) perspectives of emotion activation (Cornelius, 1996). Arnold (1960) was first to suggest a cognitive approach to emotion activation, namely *appraisal* as opposed to Charles Darwin's *evolved adaptations* (emotions are evolved phenomena with an important survival function) or William James's *perception* (emotional experiences were produced by sensing bodily changes). Arnold did not ignore the importance of an individual's past experience or perception in the process of experiencing emotion, but she emphasized the critical role of personal relevance of the situation in relation to personal aspirations for emotion to be activated. Appraisal is primarily the manifestation of cognitive processes, which are automatic and may happen without the involvement of higher level intellectual processes (Cornelius, 1996).

Features of the stimuli that activate emotions can be described as universal antecedents, defined in term of appraisal dimensions, which make emotions and the accompanying responses predictable phenomena. In his "Laws of emotion," Frijda (1988) studied the effect of cognitive appraisals and evaluation of events on emotion activation. He compiled a set of laws that believed to be responsible for the determination of emotional reactions and responses. For example, Frijda's Law of Apparent Reality: "Emotions are elicited by events appraised as real, and their intensity corresponds to the degree to which this is the case" (Frijda, 1988, p. 352), emphasizes the importance of perception in activating emotions. Hence, the perception of imminent risk warrants concern even though the event did not actually occur. For example, environmentalists and concerned citizens urge governments to ratify and implement the Kyoto Protocol for the reduction of greenhouse gases based on their perception of a global warming threat as a result of the increase in the emission of gas pollutants. Another law is the Law of Concern: "Emotions arise in response to events that are important to the individual's goals, motives, or concerns" (Frijda, 1988, p.351). This law explains, for example, why local residents reacted furiously when approximately 7,350 hectares (73,500,000 m^2) of land, encompassing the municipalities of Pickering, Markham and Uxbridge in the province of Ontario, were expropriated by the Government of Canada in early 1970s for a potential international airport site for the Greater Toronto Area. However, concern alone is not enough to activate emotions; the meaning of a situation is what causes emotions. Therefore, Frijda's Law of Situational Meaning: "Emotions arise in response to the meaning structures of given situations; different emotions arise in response to different meaning structures" (Frijda, 1988, p. 349), explains how events that are perceived to satisfy an individual's goals elicit positive emotions, whereas events that threaten the individual's concerns lead to negative emotions.

Ortony, Clore, and Collins (1988) view emotions as valence-based reactions to stimuli (events, agents, or objects), which are appraised according to an individual's goals, standards and attitudes. Ortony, Clore, and Collins' cognitive model for the effect of cognition on the activation of emotions, describes how cognitive processes encompass individual's appraisals of events with relation to the environment. The perceived consequences of events, actions of others, or certain aspects of objects are appraised relative to goals, beliefs, standards, and attitudes; and therefore the engendered emotions are seen as essential to managing individual's actions (Oatley, 1992).

The first elaborate appraisal theory for emotion activation is Lazarus's Cognitive-Motivational-Relational Theory. Its central tenet is that "relational meaning" is a function of the personal significance of an event, in conjunction with conditions present in the environment and personal goals. In other words, the personal construct of the salient features of the event determines the ensuing emotion (Cacioppo and Gardner, 1999; Scherer, 2001). Lazarus (2001, p. 41) explains, "The premise of appraisal theory is that people and the infrahuman animals are constantly evaluating relationships with the environment with respect to their implications for personal well-being." Lazarus (2001a,b) suggests that six appraisals, occurring consecutively in two steps, are responsible for eliciting and differentiating emotion.

The three primary appraisal components are *goal relevance*, *goal congruence*, and *type of ego-involvement*. These appraisals focus on whether the event or situation is personally relevant, thereby necessitating activating emotions. The first appraisal checks whether a personal goal is at stake: no emotion is elicited if the event is not personally relevant. The second appraisal checks how the consequence of the event can be expected to thwart or facilitate personal goals and if the event makes it harder or easer to achieve goals. Negative emotions are likely to be aroused in the former case, and positive emotions in the latter. Finally, ego-involvement appraisal examines how the situation or its consequence is related to the individual's identity, kin, or culture.

Secondary appraisals focus on issues that help determine options for coping with the consequences of an event, thereby selecting the type of emotion to be activated. The first appraisal judges *accountability* for an event: that is, who or what is responsible for it. The perception, for example, that someone else's premeditated event is incongruent with an individual's goal will likely make the individual angry rather than frustrated, especially if the event could have been avoided. The second appraisal checks for *coping potential*: that is, how much control does the individual have over the event. Coping potential appraisal determines ways to restore balance, either by accepting the consequences of the event, or by retaliating against the perpetrator. Lazarus and Lazarus (1994, p. 18) argue, "An event may activate several emotions, which change over time as the personal meaning changes with coping actions and flow of events." Finally, *future expectation* appraisal determines how likely the situation is to change, for better or for worse, in the future. This appraisal emphasizes urgency of action or avoidance strategies (Jones and Bodkter, 2001).

4.2.2 Emotion Identification

In the science of emotion, although psychologists largely agree, in the abstract, on what activate emotion, there is no single, unified cognitive appraisal theory. A number of overlapping, emotion-eliciting appraisal theories have been proposed to explain what cause the experience of specific emotion (e.g., Frijda (1986), Lazarus (1991), Ortony, Clore, and Collins (1988), Roseman (1984), Scherer (1984); Smith and Ellsworth (1985), Smith and Lazarus (1990)). The empirical study by Roseman, Antoniou, and Jose (1996) examined several alternative appraisal theories to improve the accuracy of the central appraisal dimensions and emotion scales. Roseman, Antoniou, and Jose (1996), Roseman (2001), and Roseman and Evdokas (2004) suggest a structural theory of appraisals in which seven dimensions are used to determine what activate each of the seventeen emotions that are listed in Table 4.1: (1) *unexpectedness*: whether an event is unexpected or is not unexpected; (2) *situational state*: whether one wants to keep something pleasurable or get rid or avoid something painful (motive-consistent/motive-inconsistent); (3) *motivational state*: whether an event will lead to getting less of something undesired or getting more of something desired (aversive/appetitive); (4) *probability*: whether the motive-relevant aspect of an event is merely possible or definitive (uncertain/certain); (5) *agency*: what or who caused the motive-relevant event (circumstances/other person/self); (6) *control potential*: can anything be done to the motive-relevant aspect of the event (low/high); (7) *problem type*: whether the motive-inconsistent event is unwanted because it blocks the attainment of a goal or unwanted because of some inherent characteristics (behavioral/ characterological).

The tenet of Lazarus's appraisal theory is that emotions are the direct consequences of the relevant goal/need and the "coping strategy" that determines the appropriate response. Roseman (2001, p. 76) views these emotional responses as "interrelated and integrated," forming an adaptive profile corresponding to coping strategies, as shown in Table 4.1.

Table 4.1: Adaptive Profile and Coping Strategy of Emotions (Adapted from Roseman, 2001)

		Response		Coping Strategy	Adaptive Profile
Emotion		Behavior	Emotivation		
1	Frustration	Exert effort	Overcome	Move against it	Collision
2	Anger	Hit, criticize,	Hurt, retaliate	Move against other	
3	Guilt	Reproach, punish self	Redress	Move against self	
4	Fear	Vigilance, inhibition or run	Prevent or get to safety	Prepare to move away from or to stop moving toward it	Avoidance
5	Sadness	Inaction	Recover	Stop moving toward it	
6	Distress	Move around, leave	Terminate, get out	Move away from it	
7	Dislike	Expel	Terminate, get out	Move away from other	
8	Regret	Do differently, do over	Correct, improve	Move away from self	
9	Disgust	Expel	Terminate, get out	Move it away from you	Exclusion
10	Contempt	Look down on, reject	Exclude	Move other away	
11	Shame	Withdraw	Get self out of sight	Move self away	
12	Surprise	Interrupt, take information	Understand	Suspend action and process information	Pose
13	Hope	Anticipate; approach	Get closer, make happen	Prepare to move toward, or stop moving away from it	Approaching
14	Relief	Rest, relax	Return to normal state	Stop moving away from it	
15	Joy	Jump, act	Sustain	Move toward	
16	Love	Touch, hold	Attach	Move toward	
17	Pride	Exhibit, assert	Recognition	Move toward self	

The perception of physical or psychological restraint from a desired goal will likely activate anger, especially if the obstruction has a long-term effect and is premeditated by someone perceived to be unfair or to have an undeserved right (Lazarus and Lazarus, 1994). Frustration, on the other hand, is a benign form of anger, in a situation where achieving the goal is merely delayed (Izard, 1977) by someone acting unintentionally, or where the situation could not be avoided. The coping strategy in these cases will involve an adaptive profile *collision*, corresponding to moving against the object instigating the event, thereby seeking to gain control of the situation and restore balance. Anger and frustration are two emotions that are considered under this adaptive profile because of their roles in precipitating hostile and aggressive actions (Izard, 1977). The difference between these two emotions is that anger could lead to physical aggression with the intention of harming and defeating the perpetrator (Izard, 1977), whereas frustration manifests itself as a motivation to retaliate. In this context, the movement metaphor depicts action readiness: feelings, thoughts, and actions. The action tendency in the case of anger will be more hostile than when the emotion is frustration.

Fear is usually felt in response to the perception of peril. The meaning centers on survival, security, and preservation of identity, when the threat is beyond control, unknown, or cannot be anticipated (Izard, 1977; Lazarus and Lazarus, 1994). The adaptive profile against fear is avoidance, which corresponds to moving away from the subject (Roseman, 2001). Fear can lead to a freezing effect, making the subject impotent and unable to respond to the cause of the emotion. In many situations, anger is used to mask fear (Izard, 1977), and to mobilize retaliatory action.

The third adaptive profile is *exclusion*, which includes the emotions of disgust, contempt and shame. The coping strategies of these emotions involve an individual's responses that exclude a stimulus (moving it away).

Positive emotions, such as hope, relief, joy, love, and pride, have an adaptive profile of *approaching*, which corresponds to a strategy of moving toward what or who instigates the emotion. With these emotions, individuals are usually imbued with the sense if trust and content as well happy feelings.

4.3 Emotion in Conflict

The proposition that conflict is laden with negative emotion is certainly recognizable in the isomorphism between the three characteristics of a conflict and Lazarus's appraisal dimensions. Conflict ensues when a situation or event is perceived (i.e., has relational meaning) as influencing a personal goal/need (i.e., is goal-relevant) in a way that makes it harder to achieve that goal/need (i.e., is goal incongruent).

The secondary appraisals determine the type and intensity of negative emotion activated. In conflict, the perception that someone else's action interferes with the individual's personal goal/need (i.e., a judgment of accountability) is more likely to generate negative emotion with action tendency, such as attacking or excluding. Examples of such emotions are anger and contempt, depending on whether there is something that might be done (i.e., coping potential). High coping potential empowers an individual with options other than confrontation or exclusion, since he or she will be less desperate; whereas if the event is controlled by the self or circumstances, it is more likely that the emotion generated will be characterized by an action tendency of accommodation. Examples of such emotions are guilt and frustration. On the other hand, the intensity of emotional experience varies with the momentarily perceived importance of the goals and concerns (Clore, 1994). The long term implication of goal/need interference determines the immediacy of the situation; the potential future repercussions, in turn, determine the intensity and extent of an individual's negative emotion.

The combination of these appraisals in conflict brings about a situation that is laden with cognitive appraisals and affective reactions (Hammer 2001). But, there are striking differences in peoples' interpretations of events, which account for a diversity in the observed emotions (Izard, 1977). Furthermore, emotions are not equally or similarly manifested and influential in all conflict situations; conflict over issues that directly affect identity, and survival is more likely to be emotional than conflict affecting interests and goals. The sociological and cultural settings, therefore, of the situation are crucial in determining which emotions are likely to be activated, how they are experiences, interpreted, and expressed (Shott, 1979).

4.4 Summary

This chapter introduces the postulate that emotion is an essential ingredient in conflict analysis. It begins by providing various meanings of conflict; then it introduces Lazarus's Cognitive-Motivational-Relational theory and Roseman's structural model of appraisals, which uses seven dimensions to determine the appropriate activated emotion in response to a stimulus. The proposition that conflict is laden with negative emotion can be inferred from observing the isomorphism between the three features that cause conflict and appraisal dimensions for emotion activation. In the next chapter, the principle of possibility, which is based on Damasio's somatic marker hypothesis, is introduced to account for the effects of emotion in envisioning outcomes in conflict. Then, the US-North Korea dispute over nuclear proliferation is used to illustrate the application of the possibility principle.

Chapter 5
Emotion and State Identification in the Graph Model

5.1 Emotion Identification in Conflict

Emotion identification is challenging and requires the use of psychometric methods in a laboratory environment. Typically, emotion elicitation models are based on the use of questionnaires or interviews. The goal of a questionnaire or an interview is to retrospectively identify emotion eliciting events or introspectively anticipate emotion in response to self-observed or simulated (experimental simulation) events (Schorr, 2001). Currently, techniques are being developed to help psychologists in the recognition of emotions from vocal cues (Nakatsu, Nicholson, and Tosa, 2000; Nicholson, Takahashi, and Nakatsu, 2000) and from facial expressions (Granato and Bruyer, 2002). Accurate correlation of the experienced emotion to a provoking event and reliable differentiation of discrete emotions (e.g., is the elicited emotion fear or anger?) are some of the major challenges facing psychologists in the identification of appraisal dimensions (Roseman, 1991).

Furthermore, employing and appraisal model requires far knowledge about DMs: their deep-seated needs, their control potential (relative power), and the degree of interference among DMs. Fortunately, in conflict a rudimentary appraisal procedure can be used to determine each DM's emotion. The three appraisal dimensions from Roseman's structural theory of appraisals (Roseman, Antoniou, and Jose, 1996; Roseman, 2001; Roseman and Evdokas, 2004) are shown by the diamond-shaped nodes in Figure 5.1.

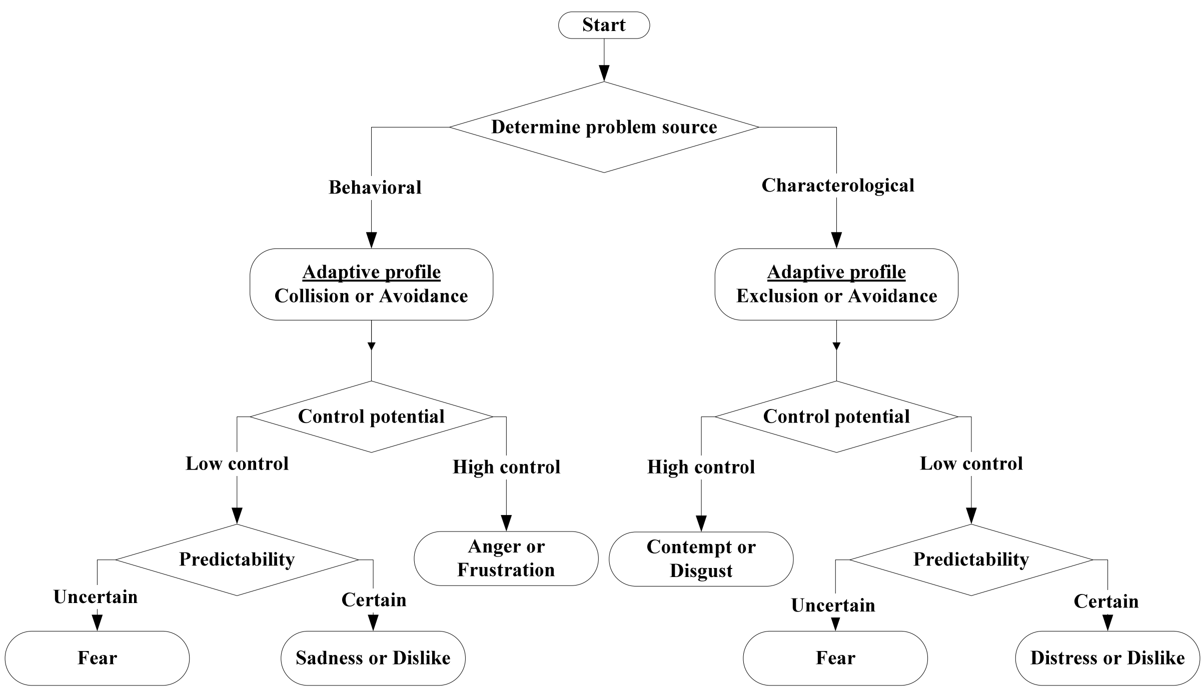


Figure 5.1: Model of emotion identification in conflict.

By definition, a conflict is a situation in which there is a perception of motive-inconsistent actions among DMs. This perception causes the activation of negative emotions.

Differentiating the type of negative emotion requires establishing a number of checks that determine the appropriate adaptive profile and response strategy (see Table 4.1). First, the source of a motive-inconsistent action (problem source): if an opponent's action causes the problem (behavioral), then an emotion with an adaptive profile of *collision* or *avoidance* is likely to arise. But if the problem is caused by the opponent's character (characterological), then an emotion with an adaptive profile of *exclusion* or *avoidance* is more likely to ensue. A behavioral problem source may cause a DM to feel angry, frustrated, frightened, or sad; whereas, if the problem source relates to the opponent's personality rather than his or her action, then the DM may experience disgust, contempt, fear, or distress. Second, the ability to control or eliminate a motive-inconsistent event is an indication of the degree of DM's control (or coping) potential. Perceiving a high control potential is more likely to engender a contending emotion, such as anger, frustration, contempt, or disgust; whereas a low control potential is more likely to engender an accommodating emotion, such as fear, sadness, dislike, or distress. Finally, a DM's ability to predict what is going to happen in the future (certain predictability) is likely to activate sadness, distress, or dislike, whereas, the DM's inability predict the future (uncertain predictability) is more likely will activate fear.

5.2 The Possibility Principle

In social interactions, people evaluate information not only logically but also with respect to its ability to help achieve personal goals. Recent developments in neurobiology and psychology strongly reveal the inextricable association between brain structures that are responsible for cognitive processes, especially in the ventromedial prefrontal cortex, and structures that are tied to processing emotion in the limbic system (Bechara and Damasio, 2005; LeDoux, 2000). Among others, Damasio (1994, 2003) believes that reasoning is guided by the emotive evaluation of an action's consequences. According to Gazzaniga, Ivry, and Mangun (2002, p. 450), "Limitations in information processing coupled with the need for expediency favor a faster [brain processing] system that can quickly eliminate actions associated with unpleasant consequences, while boosting those that experience has shown to be rewarding," especially in their effects on social choices (Bechara and Damasio, 2005). Damasio (1994) suggests that the somatic markers highlight options that have positive predicted outcomes and inhibit any tendency to act on options with negative predicted outcomes. Therefore, when we face an outcome connected with a given response option, we experience body-related responses (i.e., feelings), negative or positive, which are associated with previous emotional experiences (Bechara and Damasio, 2005). These somatic markers facilitate decision making by influencing candidate's responses (or choices) based on their affective values.

Somatic markers serve two functions: 1) they focus attention and working memory on negative or positive outcomes, thus acting as a warning or incentive mechanism, and 2) they decrease the search space (the scope of alternatives). The somatic markers, therefore, increase the accuracy and efficiency of the decision process by automating the qualification of prediction mechanisms and by forcing the decision maker to scrutinize the analysis when an option is marked as unfavorable.

Damasio's somatic marker hypothesis that emotion influences how individuals discern the environment and what choices they make in social and cultural settings is used to incorporate emotion into the Graph Model for Conflict Resolution. A new principle is introduced, which is based on the proposition that the role of emotions is to focus attention on salient states (or options), narrowing or expanding the range of perceived states (or options) according to the emotion experienced. Hence, to operationalize this proposition into a new conceptual framework that expresses the effects of emotion in the Graph Model for Conflict Resolution, the following principle is proposed:

> *The possibility principle: emotions play a central role in determining whether a feasible state is perceived as potential or hidden, reflecting its visibility in the conflict model (i.e., whether it is apprehended by the DM who controls transitions from the current position to his or her attainable states).*

In the option form of the graph model, relationships among a DM's options typically determine the feasibility or infeasibility of states. As already discussed in Chapter 2, depending on the situation, constraints used in identifying infeasible states may include: (1) contingent options (the availability of some options is conditional on the choice of others); (2) mutually exclusive options (some groups of options are incompatible); (3) obligatory options, where at least one option must be chosen from a set. This is called an "at least one" constraint (Hipel, Kilgour, Fang, and Peng, 1997).

Hence, a feasible state is one that can be carried out or brought about without violating any constraints, whereas an infeasible state is one that cannot be realized. To include a component of emotion as proposed in the concept of possibility, a classification of the feasible states based on the emotional content of the situation is proposed. The conventional set of feasible states, S, is partitioned, for each DM $i \in N$, into the three subsets, as illustrated in Figure 5.2 and explained below:

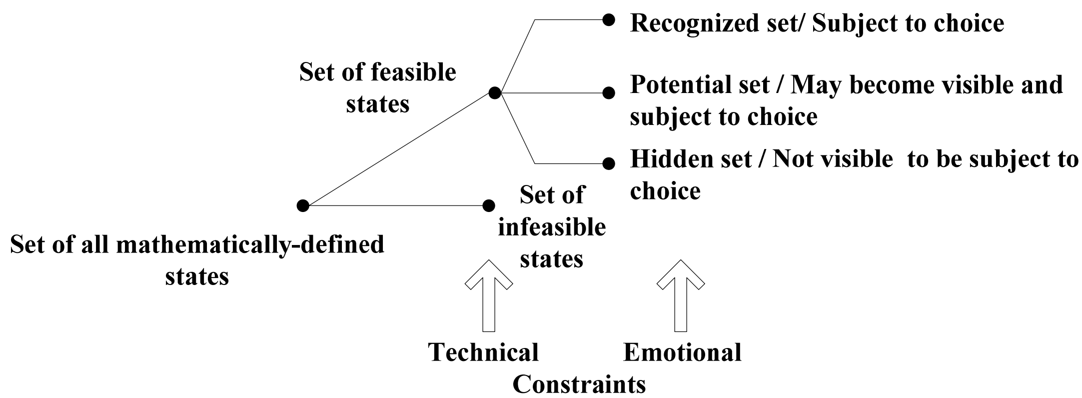


Figure 5.2: The possibility principle.

1. *Hidden states*, H_i, which cannot occur due to the presence of negative emotion that have adaptive profiles of avoidance and collision, such as fear and anger, respectively. It is unlikely that DM *i* will apprehend hidden states unless certain strong negative emotions have been diminished. In other words, a hidden state is invisible for a DM and a rejected possibility; negative emotion blocks it.

2. *Potential states*, P_i, which cannot occur due to the lack of positive emotion necessary to allay concerns and disseminate trust among DMs (Dunn and Schweitzer, 2005). It is unlikely that DM *i* will consider these states unless he or she is emotionally motivated. Hence, expressing the appropriate positive emotion, such as joy and love, enables DM *i* to discern potential states.

3. *Recognized states*, S_i, consisting of all states of S not included in H_i or P_i. These states may not be uniformly discernable to all DMs. Different recognized state sets may exist in a conflict model for each DM, dependent on which sets are categorized hidden and potential.

Emotion, therefore, plays a central role as a graph modifier in conflict analysis. Accordingly, we can surmise that positive emotion will make the set of potential states visible, and thereby expand the graph model of the conflict. Negative emotion, especially negative emotion with an adaptive profile of avoidance, such as fear, dislike, distress, and sadness, makes the set of hidden states invisible and thereby restricts a graph model of the conflict. The main difference between potential and hidden states is that the former are invisible due to missing emotions, usually positive emotions that promote trust and rapport among decision makers, while the latter are invisible due to the presence of negative emotions such as anger, frustration, and fear.

With one exception, the suggested categorization of the effects of negative and positive emotion on the graph model is common. In certain emotional conflicts, a self-destructive future may be a state recognized by a DM because of the presence of intense anger, provided that this future engenders short-term gains with a sense of glorification or martyrdom. For example, the DM may inflict grave harm and pain upon other DMs irrespective of the long-term consequences of such an act. Notwithstanding, the same future may be hidden to other DMs because of fear. Thus, an angry suicide bomber under the illusion of martyrdom resorts to a dramatic act that hurts an opponent, even though he or she knows that vengeance will follow.

Awareness of the presence and causes of emotions in the conflict and an empathetic understanding of their affects on DMs' perceptions provide more realistic and expedient integration of the possibility principle into the Graph Model methodology. To identify states that are reasonable and emotionally harmonious from the point of view of each DM, usually least preferred states are candidates for elimination. This has the effect of restricting the set of feasible states as per each DM's perception of the conflict. Rigorous sensitivity analyses of the model can be used to examine whether assumptions about hidden and potential states affect the results of a stability analysis. For instance, if the results do not change substantially, then accounting for DMs' emotions in the conflict makes the graph model simpler but keeps the results intact. On the other hand, if the results change, then the analyst should be cautious about removing states from the graph model and seek further information.

5.3 Case Study: US-North Korea Conflict

5.3.1 Standard Modeling and Analysis

The end of the Korean War (1950-1953) reinforced the division of the Korean peninsula both geographically, into North and South, and ideologically, into totalitarian and quasi-democratic. For almost fifty years, the hostile relationship between the United States of America (US) and Democratic People's Republic of Korea (DPRK) has been ascribed to enmity. Recently, the tension surrounding this relationship heightened sharply. Despite its economic devastation, North Korea strengthened its military. Defying the US, North Korea admitted to having a secret uranium enrichment program and started reprocessing fuel rods at its nuclear complex at Yongbyon, which would produce weapons-grade plutonium. It also continued developing long-range ballistic missiles.

Officials in the US government have routinely characterized Pyongyang as a threat to the US's national interests and emphasized the need for preemptive, decisive attacks to thwart North Korea. After the September 11, 2001 terrorist attacks, the US administration became very aggressive on national security issues. Foreign policy was based on a preemptive defense doctrine, and the slogan “you are either with us or against us,” provided no assurance or comfort to friends or foes. The US fears North Korea may sell nuclear technologies to countries such as Iran, Syria, and Libya, for hard currency, and may even supply nuclear weapons to terrorists.

As of June 2003, North Korea had two options: *abandon* its nuclear weapons program by freezing all development activities at the Yongbyon nuclear facility, including the highly enriched uranium program; or *curtail* its conventional weapons program by reducing spending and stopping the production, testing, deployment, and sale of ballistic missiles. On the other hand, the US has three options: *engage* in direct negotiation with North Korea; *adopt* an aggressive approach perhaps including a military strike; and *continue* pressuring North Korea through sanctions and isolation, countering South Korea’s Sunshine Policy that seeks social and economical integration in the Korean peninsula. The left column in Table 5.1 lists the two decision makers and their options.

Table 5.1: Decision Makers and Option in the US-North Korea Conflict

Players and Options	**Status Quo**	
North Korea		
1. *Abandon*: stop its nuclear weapon program	N	North Korea’s Strategy
2. *Curtail*: reduce its conventional weapons program	N	
US		
3. *Negotiate*: engage in direct negotiations with North Korea	N	US’s Strategy
4. *Attack*: adopt an aggressive, military posture	N	
5. *Pressure*: influence North Korea through sanctions and isolation	Y	

A state (or policy scenario) is defined as a column of Ys and Ns, where a “Y” opposite an option means the option is selected, and an “N” means the option is rejected. For example, the column with four Ns followed by one Y, shown in Table 5.1, is the status quo state, in which North Korea has adopted the strategy of not taking any of its options while the US is pressuring North Korea by selecting option 5.

In this conflict model, there are 32 (25) mathematically-defined states. However, many of these states are infeasible. Those states that contain mutually exclusive options (e.g., US attacks and negotiates) or highly unlikely strategies (e.g., US attacks or pressures and North Korea abandons or curtails) must be removed. Table 5.2 shows the decision makers and the feasible states; as noted, state 10 is the status quo at the time of modeling.

Table 5.2: Feasible States in the US-North-Korea Conflict

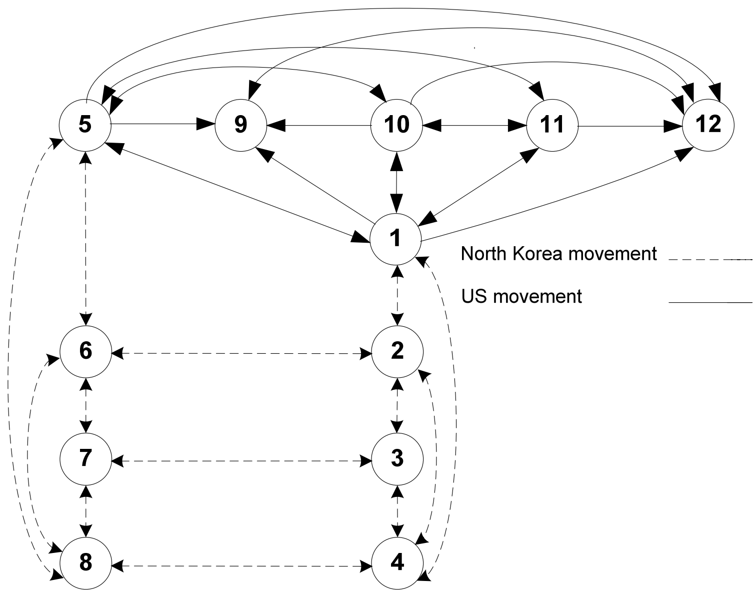
	States											
North Korea	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Abandon	N	Y	N	Y	N	Y	N	Y	N	N	N	N
2. Curtail	N	N	Y	Y	N	N	Y	Y	N	N	N	N
US												
3. Negotiate	N	N	N	N	Y	Y	Y	Y	N	N	Y	N
4. Attack	N	N	N	N	N	N	N	N	Y	N	N	Y
5. Pressure	N	N	N	N	N	N	N	N	N	Y	Y	Y

The preference structure of each DM among feasible states is expressed ordinally by ranking the states from the most to the least preferred, where ties are allowed. Note that US policy towards North Korea is assumed to be hostile, with no consideration given to North Korea's fundamental needs. Table 5.3 shows each DM's preferences—from most preferred states at the top to least preferred at the bottom. Equally preferred states are shown in the same row. (The symbol $\succ$ indicates the direction of a DM's preference between two states; for example North Korea prefers state 5 to state 11, written $5 \succ_{NK} 11$.)

Table 5.3: Decision Makers' Relative Ranking of States

North Korea Preference Ranking	States
US: Negotiate unconditionally	5
US: Negotiate and Pressure unconditionally	11
Do nothing	1
US: Negotiate and North Korea: Abandon or Curtail	7,6,8
Status Quo	10
US: Attack	9,12
US: Do nothing and North Korea: Abandon or Curtail	3,2,4
US Preference Ranking	**States**
North Korea: Abandon or Curtail unconditionally	4,2,3
US: Negotiate and North Korea: Abandon or Curtail	8,6,7
Do nothing	1
US: Negotiate and Pressure unconditionally	11
US: Attack and Pressure	12
US: Attack	9
Status Quo	10
US: Negotiate unconditionally	5

The integrated graph model for the conflict is shown in Figure 5.3, where the number shown in a node refers to the feasible state defined in Table 5.2, and each DM's preferences are expressed below the graph by ranking the states from most preferred on the far left to least preferred on the far right, where equally preferred states are contained within parentheses. The arcs represent the unilateral moves by each DM from one state to another. For example, the arc from state 10 to state 9 in Figure 5.3 represents the US moving in one step from the status quo to a strategy of attacking, while North Korea does not change its options. It is assumed that the US attack option is irreversible; once it has been selected, there is no way back—the damage is done. An inherent advantage of the graph model is that it directly accounts for such irreversible moves. One point is repeated for emphasis: all DMs' graphs have the same set of states, which reflects the implicit assumption that all DMs have the same view of the conflict.



North Korea's relative preference ranking of states $5 \succ_{NK} 11 \succ_{NK} 1 \succ_{NK} (7,6,8) \succ_{NK} 10 \succ_{NK} (9,12) \succ_{NK} (3,2,4)$

US's relative preference ranking of states $(4,2,3) \succ_{US} (8,6,7) \succ_{US} 1 \succ_{US} 11 \succ_{US} 12 \succ_{US} 9 \succ_{US} 10 \succ_{US} 5$

Figure 5.3: Standard graph model for the US-North Korea conflict.

For convenience, the decision support system GMCR II (Fang, Hipel, and Kilgour, 2003a,b; Hipel, Kilgour, Fang, and Peng, 1997) is used to analyze the current conflict model according to different solution concepts. As shown in Table 5.4, the analysis reveals the equilibria are states 1 (do nothing) and 12 (US attack and pressure), which are stable for all solution concepts; states 6 and 8, which are stable for general metarationality and sequential stability; and state 7, which is stable for all solution concepts except Nash Stability.

However, this model is unrealistic in certain important ways. The 'do nothing' option will give North Korea the time it needs for the development of its enriched uranium program, while an 'attack' could usher the world into a nuclear catastrophe—neither state is a preferred resolution of the US. Accordingly, the effect of emotions is considered next in the conflict model using the possibility principle.

Table 5.4: Equilibria for the US-North Korea Conflict Model

	States				
North Korea	**1**	**6**	**7**	**8**	**12**
1. Abandon	N	Y	N	Y	N
2. Curtail	N	N	Y	Y	N
US					
3. Negotiate	N	Y	Y	Y	N
4. Attack	N	N	N	N	Y
5. Pressure	N	N	N	N	Y
Solution Concepts					
Nash Equilibrium	√				√
General Metarationality	√	√	√	√	√
Symmetric Metarationality	√		√		√
Sequential Stability	√	√	√	√	√
Limited-move Stability	√		√		√
Nonmyopic Stability	√		√		√

5.3.2 The Possibility Principle in the US-North Korea Conflict Model

The relationships between the US and North Korea went through a cycle of policies of containment, engagement, and confrontation, but an element that remained constant was emotion. To a large degree, and for different reasons, the policies of both DMs are influenced, guided, and managed by the emotions of fear and anger. North Korea alleges that its nuclear and missile programs do not serve any immediate political or offensive purpose—rather, they are viewed by the DRPK as essential for survival in the long term (Laney and Shaplen, 2003). Many analysts believe that it is highly unlikely North Korea will use nuclear weapons against the US unless the regime in Pyongyang is imperiled (Bennett, 2003; Feffer, 2002); the missile program is a source for hard currency that sustains Kim Jong Il in power. The US-led war against the former Iraqi regime reinforced North Korea's sense of its vulnerability, and its hostile attitude toward the US. On April 7, 2003, the Korean Central News Agency (KCNA) reported that a Foreign Ministry spokesperson stated: "Only the physical deterrent force, tremendous military deterrent force powerful enough to decisively beat back an attack supported by any ultra-modern weapons, can avert a war and protect the security of the country and the nation. This is a lesson drawn from the Iraqi war."

Since September 11, 2001, the Bush administration has eschewed any direct negotiation with Pyongyang, while maintaining hostile rhetoric against North Korea. According to the September 2002 document "National Security Strategy of the United States of America" (The White House, 2002), the US fears a new form of threat, terrorists using weapons of mass destruction. In his State of the Union address in January 2002, President Bush labeled North Korea a member of the "axis of evil," along with Iraq and Iran. The US believes that its security interests are threatened by North Korean nuclear weapons and missile technology. Moreover, North Korea's development of nuclear weapons will encourage other states to do likewise; the US and other powers worked hard to stop nuclear proliferation during the cold war.

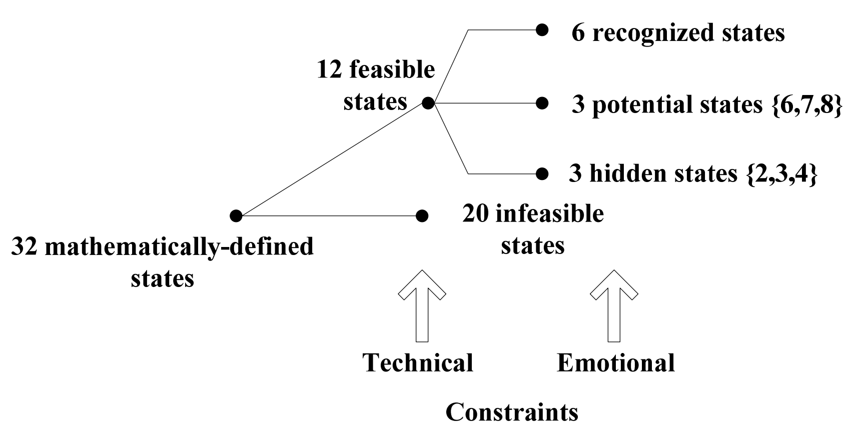
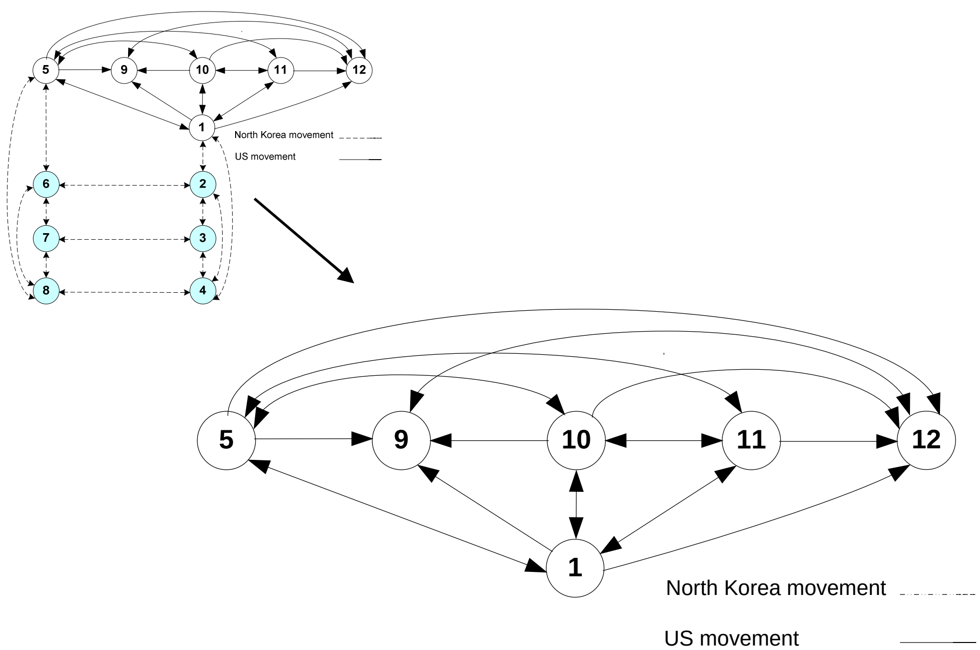


Figure 5.4: Potential and hidden states for the US-North Korea conflict model

To account for the role of emotion in the conflict model, the sets of potential and hidden states are defined and included in the conflict model, as shown in Figure 5.4. States 6, 7, and 8 are those in which the US engages in direct negotiation with North Korea, perhaps motivating North Korea to abandon or curtail its nuclear and missile programs. Unless the US can address Kim Jong Il's fears by recognizing the legitimacy of the ruling regime (for example, by entering into a nonaggression pact with North Korea), these states are not visible to North Korea. Only by building confidence and trust and by committing to address North Korea's economic and security needs will these states become realistic. The US can start by supporting South Korea's Sunshine policy, changing its hostile posture, and agreeing to engage in sincere negotiations.

States 2, 3, and 4 (see Table 5.2) are hidden to North Korea, because of years of enmity and distrust. At these states, North Korea unconditionally abandons or curtails its nuclear and missile programs. However, fear and anger make these states invisible and hence unrealizable. Although it is possible that the inability to perceive some states may change a DM's relative preferences over the remaining states, it is assumed here that the DM's preference between perceived states will be unchanged. Figure 5 depicts the new conflict model with the two sets of states disappearing from the model. Only the US controls movements in this model.

Analyzing this new model using GMCR II reveals that states 1 and 12 are still equilibria and stable for all solution concepts. The conflict model has degenerated to a single decision maker problem, as the US controls all available state-to-state transitions. As controlling DM, the US can either appease North Korea (by doing nothing) or it can deliver a military strike. Both resolutions would be dreadful. In reality, North Korea is sending ambiguous messages about its intentions and at the same time is continuing to develop its weapons program. Meanwhile, the US is avoiding direct negotiations on the grounds that the problem of nuclear proliferation concerns the entire Korean peninsula and the region, and therefore requires a multilateral framework. The new conflict model gives a more realistic picture of the severity of the situation. Without considering the role of emotions, the results in Table 5.4 may give the wrong impression—states 6, 7, and 8 are attractive to the US but only a mirage—visible to the US only. North Korea will not consider abandoning or curtailing its weapons programs while the US is showing a hostile posture toward it. Unless the US starts considering North Korea's emotions, the crisis may turn into a catastrophe.



North Korea's relative preference ranking of states $5 \succ_{NK} 11 \succ_{NK} 1 \succ_{NK} 10 \succ_{NK} (9,12)$

US's relative preference ranking of states $1 \succ_{US} 11 \succ_{US} 12 \succ_{US} 9 \succ_{US} 10 \succ_{US} 5$

Figure 5.5: Modified graph model for the US-North Korea conflict model.

5.3.3 A Breakthrough in the Situation!

On August 27, 2003, delegates from North Korea, South Korea, USA, Japan, China, and Russia met in Beijing, China in six-way talks to discuss the tension in the Korean peninsula. Assistant State Secretary James Kelly, head of the US delegation, stated that US willingness to discuss security assurance and political and economical benefits for North Korea is conditional upon complete, irreversible, and verifiable elimination of North Korea's nuclear programs (BBC News, 2003). The US, according to Kelly, does not consider a non-aggression treaty as appropriate or necessary, and therefore will not pursue one.

North Korea, on the other hand, demanded that the US terminate its hostile policy toward the DPRK as a precondition for discussing further matters related to its nuclear programs. Only after the US removes North Korea from its "axis of evil" list and signs a non-aggression agreement will the latter consider dismantling its nuclear programs, according to North Korea's Vice-Minister of Foreign Affairs. China, Russia, and South Korea urged the US and North Korea to work out a simultaneous process for solving the nuclear issue, stressing the importance of signing a non-aggression treaty as a trust-building bridge to complete denuclearization of the Korean peninsula and economic prosperity in the whole region (KCNA, 2003). As a demonstration of good faith, North Korea allowed a group of American experts to visit Yongbyon in January 2004 to prove that it has developed weapons-grade plutonium. Simultaneously, the Bush administration played down its aggressive tone and war-drums rhetoric, at least in the media. Perhaps there are steps each party can take in order to break the standoff.

The US can alleviate North Korea's concerns by agreeing to engage in direct talks with North Korea, under the umbrella of the six-way meeting. This means that the US will sincerely consider abandoning its hostile posture in an effort to gain North Korea's trust. Not only will that make the possible states 6, 7, and 8 visible, but the preference structures of both players will change as well. The new preference ranking of both DMs is shown in Table 5.5.

Table 5.5: Decision Makers' New Relative Preference Ranking of States

North Korea Preference Ranking	States
US: Negotiate unconditionally	5
US: Negotiate and North Korea: Curtail	7
US: Negotiate and North Korea: Abandon	6
US: Negotiate and North Korea: Abandon and Curtail	8
Do nothing	1
US: Negotiate and Pressure unconditionally	11
Status Quo	10
US: Attack	9.12
US Preference Ranking	**States**
US: Negotiate and North Korea: Abandon and Curtail	8
US: Negotiate and North Korea: Abandon	6
US: Negotiate and North Korea: Curtail	7
US: Negotiate unconditionally	5
Do nothing	1
US: Negotiate and Pressure unconditionally	11
Status Quo	10
US: Attack and Pressure	12
US: Attack	9

Analyzing the new conflict model reveals possible resolutions that were not available in the original model, as shown in Table 5.6. The most important revelations are the stabilities of states 5 and 7, where the US accepts direct negotiations with North Korea. In state 5, the US move is unconditional, but aimed to induce North Korea to abandon or curtail its weapons programs; in state 7, North Korea in fact agrees to curtail its missile program.

Table 5.6: New Equilibria for the US-North Korea Conflict Model

	States		
North Korea	**5**	**7**	**12**
1. Abandon	N	N	N
2. Curtail	N	Y	N
US			
3. Negotiate	Y	Y	N
4. Attack	N	N	Y
5. Pressure	N	N	Y
Solution Concepts			
Nash Equilibrium	√		√
General Metarationality	√	√	√
Symmetric Metarationality	√	√	√
Sequential Stability	√		√
Limited-move Stability	√		√
Nonmyopic Stability	√		√

5.3.4 Insights

The integrative analysis approach to the US-North Korea conflict, in which both emotions and reasoning are studied empathetically using the graph model for conflict resolution, is simple and consistent with reality. North Korea refuses to capitulate to US demands, and engages diplomatically with its neighboring countries China, Russia, South Korea and, to a lesser degree, Japan, in an effort to build a legitimate rationale for its cause. The US, on the other hand, justifies its policy toward North Korea within the context of its "war on terrorism." It refuses direct negotiations in an effort to internationalize the problem of nuclear weapons proliferation in the Korean peninsula.

The opportunity for dialogue was missed, however. In February 2005, the US Secretary of State called North Korea an "outpost of tyranny" and the US alleged that North Korea had sold uranium hexafluoride, which can be used to enrich uranium for nuclear weapons, to

Libya in 2001. North Korea responded by pulling out of the six-way talks and announcing that it has indeed built nuclear weapons (Economist, 2005).

If anything is to be learned in this case, it is that this conflict goes beyond what normal analysis would reveal. The struggle is over identity, self-definition, and projection into the future, all ideas that are full of emotion. If Kim Jong Il does not maintain his power and his self-definition, he will not survive. The US's main objectives are self-definition and projection into the future as a means for increasing its security and economic and military superiority. North Korea's apparently irrational behavior could be attributed to a coping strategy intended to protect and restore balance to an ego, in response to fear of the US.

5.4 Summary

This chapter extends the state identification step of the Graph Model methodology to include a postulate based on Damasio's somatic marker hypothesis. The possibility principle emphasizes the centrality of emotion in determining the visibility of states to a DM. The importance of somatic markers for making decisions is discussed. To demonstrate the new principle, the US-North Korea conflict is detailed and analyzed as an illustrative case. To account for DMs' inconsistent perceptions of a conflict, perceptual graph models and the associated graph model system are defined in the next Chapter. Then, perceptual stability analysis of the graph model system is described. The Chechnya conflict is used to illustrate the practical application of these new theoretical developments.

Chapter 6
Perceptual Graph Model for Conflict Resolution

6.1 Motivation

The possibility principle provides a framework to account for the role of emotion in strategic conflict. Subjective perceptions of particular outcomes are incorporated into a conflict model by eliminating logically valid states that are not apprehended by the DM or exposing states that are otherwise invisible. Not only may this simplify the conflict model substantially, expedite the analysis, and make it more intuitive, but also it will make the model a more realistic description of the DM's conceptualization of the conflict.

To incorporate the possibility principle within the Graph Model methodology, the steps depicted in the flow diagram in Figure 2.2 are slightly modified to use the information obtained about DMs' emotions at the modeling stage. Figure 6.1 shows how the flow diagram is augmented to include the possibility principle. Steps 1 to 3 produce the usual set of DMs' directed graphs, which can be integrated. A complete standard graph model for the conflict is obtained using every DM's relative preferences with respect to the feasible states with the integrated graph (Step 4). Applying the possibility principle in Step 5 may modify the directed graphs by expanding or restricting the set of feasible states according to the DMs' emotions.

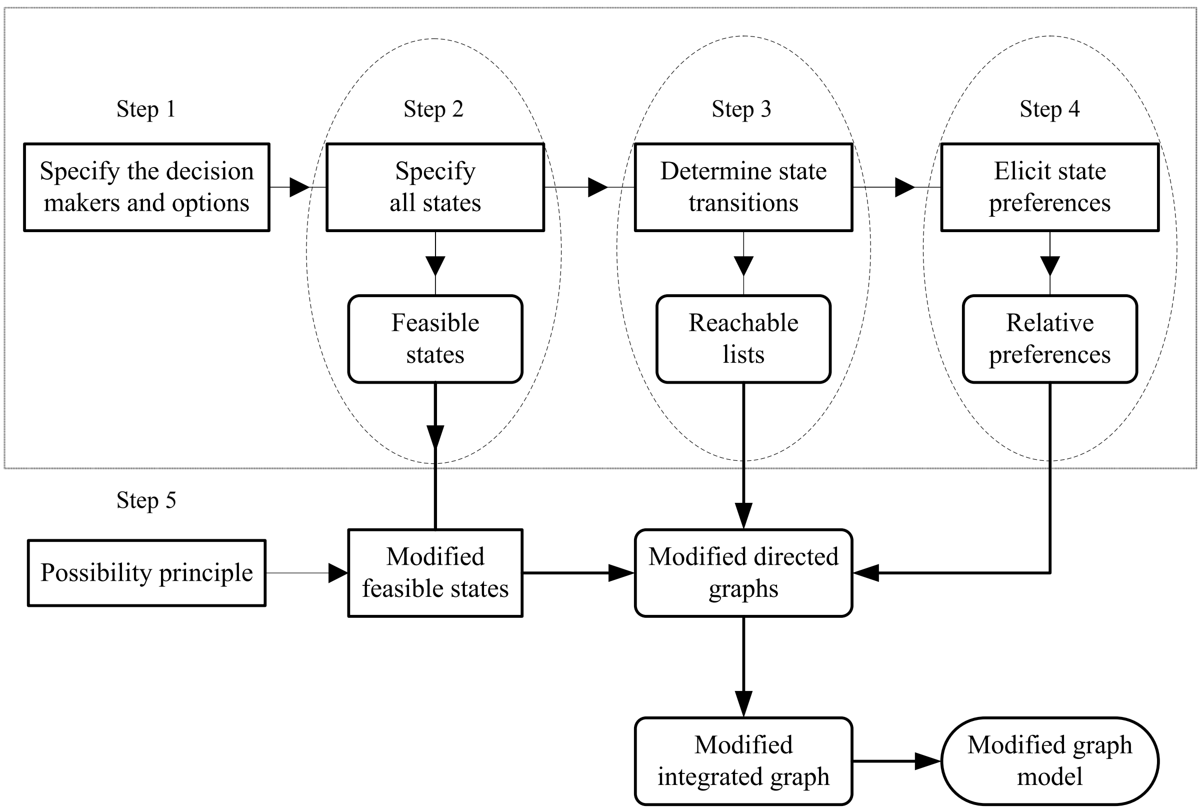


Figure 6.1: Modified flow diagram of the modeling stage in the Graph Model methodology.

State transitions may also be affected by this modification, since they are specified by a controlling DM's unilateral move from one state (source) to another (destination). If either state is removed from the model then the associated state transition must be dropped; whereas if a new state is introduced, the required means to reach that state may not be readily visible to any particular DM. Transitions to or from that state, therefore, are not necessarily available to that DM. Take for instance a bloody conflict between two DMs. Negative emotions may prevent the DMs from realizing the means to reach a peaceful resolution, albeit both would agree that such an outcome would be in their best interests.

Preference information is essential in the assessment of stability of states. DMs' preferences are less susceptible to changes in the set of feasible states. Relative preference relations among states are assumed to be preserved, and, hence, the modified graph inherits the preference information from the standard model. Consequently, modifying the set of feasible states indirectly alters the state transitions and the pairwise comparisons of states with respect to preference, which ultimately changes the graph model.

Heretofore, it was assumed that all DMs have identical state sets, which reflects the implicit assumption that all DMs are sympathetic to each others' emotions and thereby have unequivocally identical views of the possible states of the interaction. Naturally, this assumption allows all DMs' individual directed graphs to be combined into a unique integrated graph model for the conflict and facilitates stability analysis. In the US-North Korea conflict described in Section 5.3, for example, all directed graphs were integrated as shown in Figure 5.3, and stability analyses of states were based on the standard solution concepts discussed in Chapter 2, Section 2.4. But this idealization may simplify a graph model embeded with the possibility principle to the extent that its application to real-world conflict is hindered. Generally, emotion engendered in conflict may impair a DM's tendency to identify with opponents and ability to assess strategy combinations objectively. Hence, each DM develops a viewpoint that reflects its personal rendition of the conflict.

A practical model that reconciles emotion and strategy must, therefore, allow for DMs to have different apprehensions of the underlying decision problem, which violates a fundamental tenet of Graph Model methodology—that all DMs' directed graphs have identical sets of vertices (states). A perceptual system for modeling and analysis can accommodate the possibility principle within the Graph Model, allowing each DM to experience and view the conflict independently, without the need for complete awareness of others' perceptions. To guarantee this flexibility, it will be assumed that each DM is at best empathetic with his or her opponents.

Figure 6.2 is a flow diagram that shows how the possibility principle can be applied using a perceptual mapping of the standard graph model. The perceptual mapping process creates a perceptual (integrated) graph model for each DM. This model inherits its primitive information (ingredients) from the standard graph model. But inconsistencies in apprehending outcomes necessitate modification of the set of feasible states to reflect each DM's emotion and perception. Consequently, the perceived state transitions and the preferences regarding the perceived states in the DM's perceptual graph model may be affected.

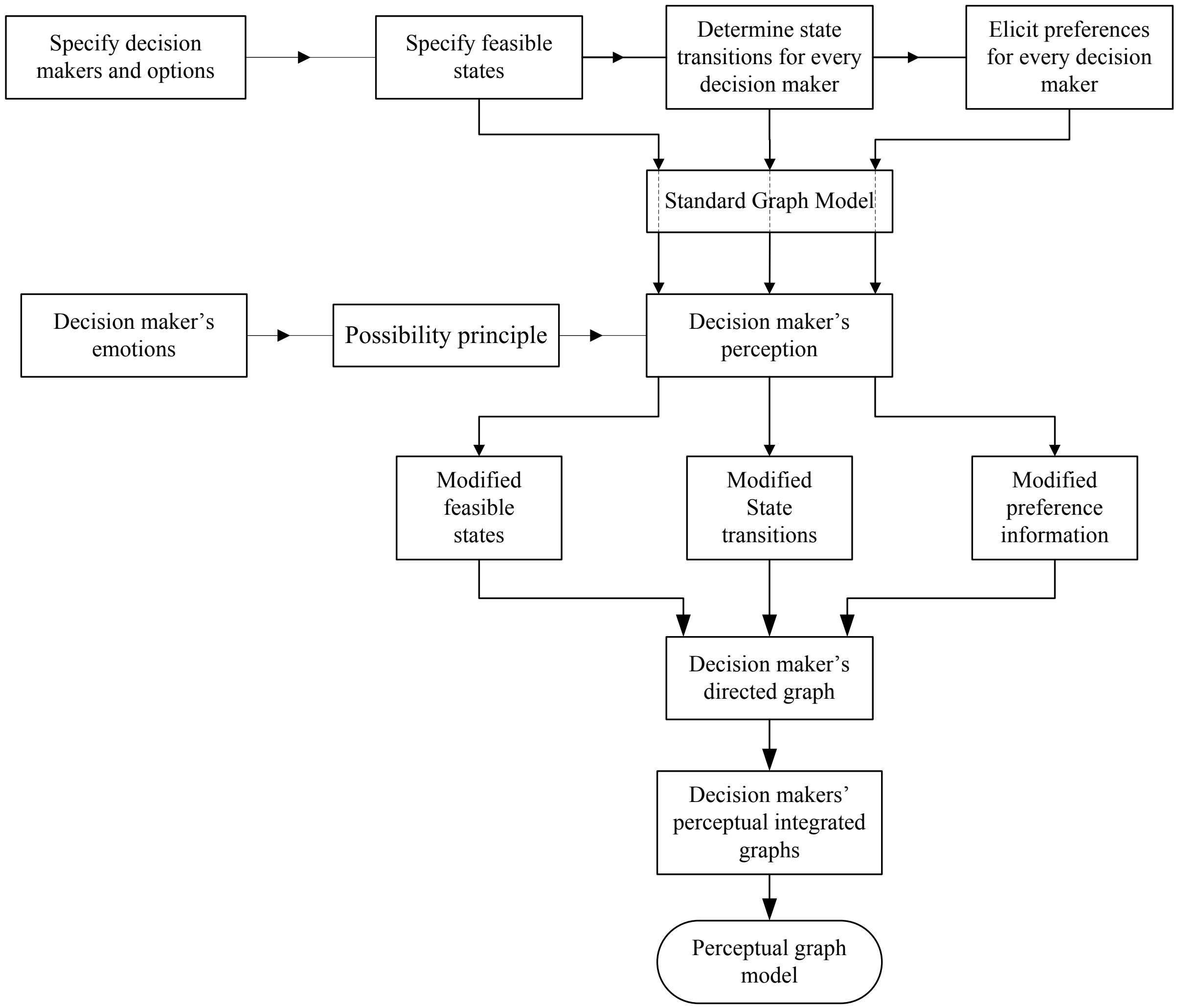


Figure 6.2: Flow diagram for incorporating the role of emotion in changing decision makers' perceptions of states in the Graph Model.

6.2 Formal Definitions

6.2.1 Standard Graph Model

The primitives of a graph model include DMs and states. A *standard* graph model can be expressed by a quartet of components:

$$G = \left[N, S, (A_i)_{i \in N}, (\succeq_i)_{i \in N} \right] \tag{0.1}$$

The set of all *DMs* is N, where $2 \le |N| < \infty$. For convenience, assume $N = \{1, 2, ..., n\}$. S is the set of states, where $2 \le |S| < \infty$. The states represent feasible, distinguishable outcomes or scenarios of the conflict, and are thought of as the vertices of each DM's directed graph. One of the states, s_0, is designated as the *status quo*, or initial state, and the conflict evolves as individual DMs unilaterally cause transitions among states. Formally, for each DM $i \in N$, $A_i \subset S \times S = \{(s_1, s_2): s_1, s_2 \in S, s_1 \neq s_2\}$ is the set of *state transitions* or arcs controlled by *i*. For $s_1, s_2 \in S$ and $s_1 \neq s_2$ (i.e., no loops are allowed), (s_1, s_2) is an arc in DM *i*'s directed graph (S, A_i) if DM *i* can cause, in one step, a transition from state s_1 to state s_2. In this case, s_2 is reachable for *i* from s_1.

An additional component of a graph model is each DM's preferences among states. A DM's preference can be expressed in a relative fashion by pairwise comparisons of states, whereby a DM prefers one state more than another or is indifferent between them. In general, for each DM $i \in N$, a complete and reflexive *weak preference relation* $\succeq_i$ expresses each DM's preferences over S. $\succeq_i$ can be decomposed into a pair of binary relations $\{\succ_i, \sim_i\}$. Conventionally, DM i *strictly prefers* s_1 to s_2, written $s_2 \succ_i s_1$, if and only if $s_2 \succeq_i s_1$ but not $s_1 \succeq_i s_2$. Also, DM i is *indifferent* between s_2 and s_1 then $s_1 \sim_i s_2$, if and only if $s_2 \succeq_i s_1$ and $s_1 \succeq_i s_2$. These relationships possess the following properties:

1. $\succ_i$ is asymmetric; i.e., for any $s_1, s_2 \in S$, $s_1 \succ_i s_2$ and $s_2 \succ_i s_1$ cannot occur simultaneously.

2. $\sim_i$ is reflexive and symmetric; i.e., for any $s_1, s_2 \in S$, $s_1 \sim_i s_1$, and if $s_1 \sim_i s_2$ then $s_2 \sim_i s_1$.

3. $\{\succ_i, \sim_i\}$ is complete; i.e., for any $s_1, s_2 \in S$, then at least one of $s_1 \succ_i s_2$, $s_2 \succ_i s_1$, or $s_1 \sim_i s_2$ is true.

Preference information can be either transitive or intransitive. Whatever the case, both the graph model and the procedures developed in this chapter can be conveniently employed for modeling and analysis. In fact, in real world conflicts relative preference relationships among states are often transitive, which allow expressing DMs' preferences by ranking (ordering) the states for each DM from most to least preferred, where ties are allowed.

In the graph model, G, DM *i*'s graph is the directed graph (S, A_i), and S is common to all DMs. In this sense, the graph model is a directed graph with multiple arcs, in which each arc is labeled with the name of the DM who controls it.

6.2.2 Perceptual Graph Model and Graph Model System

Incorporating emotion within the Graph Model methodology requires partitioning the set of states, S, into three subsets: hidden, potential, and recognized. When logically possible states are no longer achievable for one or more DMs due to emotions, the apprehension of a conflict becomes inconsistent, and resolution may become difficult to predict. Hence, it is appropriate to model the conflict using a perceptual graph for each DM to allow for differences in the DMs' perceptions. In a standard graph model, DMs' graphs are integrated into a unified model. But with inconsistent perceptions, each DM's viewpoint defines an entire conflict model.

The underlying principle of the perceptual graph model system is that the DMs' perceptions must be the basis for analysis. Even when $n = 2,$ in addition to the focal DM *i* and the opponent *j*, DM *k* is introduced to keep track of who owns the perceptual graph. Therefore, DM *k*'s set of *recognized states* defines *k*'s *perceptual graph model*, which is generally a private model.

Formally, for each DM $k \in N$, let $S_k \subseteq S$ be *k*'s set of *recognized states*, where S_k is formed by eliminating from S *k*'s hidden and potential states. Note that S_k reflects *k*'s *perception*—in particular, some states may not be discernible to all DMs in a model. Usually, it is assumed that $S_k \neq \varnothing,$ for otherwise DM *k* would not apprehend that he or she has a stake in the conflict, and thereby $k \notin N$; in fact, it is assumed that $s_0 \in S_k$. Similarly, for DMs $i, k \in N$, define S_i^k as DM *k*'s *perception* of *i*'s state set, and note that $S_i^k \subseteq S_k$. As a special case, if the focal DM is the owner of the perceptual graph, then $k = i$, so $S_i^i = S_i$.

For $i, k \in N$, define A_i^k as DM *k*'s *perception* of *i*'s state transitions. A_i^k consists of the arcs of DM *i*'s directed graph, A_i, which are wholly contained within DM *k*'s set of *recognized states*. For $k = i$, $A_i^i = A_i$ which represents DM *i*'s arcs contained in S_i. Generally, $A_i^k \subset S_i^k \times S_i^k$, and can be expressed as $A_i^k = \{(s,t) \in A_i : s,t \in S_i^k, s \neq t\}$.

Similarly, for $i, k \in N$, let $\succeq_i^k$ be DM *k*'s *perception* of *i*'s relative preferences among states. The perceived weak preference relation, $\succeq_i^k$, represents the restriction of $\succeq_i$ on S_k, and expresses *i*'s preference over S_k, as perceived by DM *k*. $\succeq_i^k$ has the same properties as $\succeq_i$; it is reflexive and complete.

Furthermore, a perceptual graph model has to keep track of what each DM knows. Conclusions drawn from analyzing a perceptual graph model are conditional upon a DM's awareness of opponents' perceptions of his or her set of recognized states. A DM who is *aware* of others' lack of perception of some states may have an upper hand in the conflict. On the other hand, a DM who is *unaware* of others' lack of perception will be under the impression that his or her model is a standard graph model. An indicator of a DM's awareness will be used to distinguish between these two cases. For DM *k* let α_k be an index that represents DM *k*'s awareness of whether other DMs' inconspicuous states are included in his or her perceptual graph model, as follows:

$$\alpha_k = \begin{cases} 0 & \text{DM } k \text{ is unaware that other DMs perceive different graph models.} \\ 1 & \text{DM } k \text{ is aware of others' inconspicuous states in } S_k. \end{cases} \quad (0.2)$$

Consequently, for $i, k \in N$ define DM *k*'s *perceptual graph model* as:

$$G_k = \left[N, \left(S_i^k\right)_{i \in N}, \left(A_i^k\right)_{i \in N}, \left(\succeq_i^k\right)_{i \in N}, \alpha_k \right] \quad (0.3)$$

where:

N is a finite set of *DMs*; $2 \leq |N| < \infty$.

S_i^k is DM *k*'s *perception* of *i*'s states; $S_i^k \subseteq S_k$.

A_i^k is DM *k*'s perception of *i*'s transitions among states.

$\succeq_i^k$ is DM *k*'s perception of *i*'s preferences.

α_k is DM *k*'s index of awareness.

In G_k, DM *k*'s viewpoint reflects his or her strategic and behavioral dispositions. All DMs' perceptions are accounted for by defining, for every DM in N, a private, perceptual graph. A *graph model system* consists of a list of all DMs' perceptual graph models:

$$\widehat{G} = \left(G_1, G_2, ..., G_k, ..., G_n\right) \tag{0.4}$$

The standard model represents a "realistic," emotionless view, which would apply if perceptions were consistent. It records states, state transitions, and preference information, which are then inherited by the graph model system. Hence, each perceptual graph model in the system is a sub-model that shares some features of the standard graph model. Commonalities among perceptual graph models may be the result of either compassionate or emotionless DMs. In the former case, all DMs share the same view, i.e., $G_1 = G_2 = ... = G_n = \widehat{G}$, while in the latter case there is only one underlying standard model.

In general, the way each DM views the conflict may be explained by a mapping process that depends on the DM's temperament. This mapping process may elicit an equally perceived, under-perceived, or over-perceived graph. An emotionless DM has a perceptual graph that is a replica of the standard graph model, whereas an emotional DM's mapping may transpose a standard graph into an under-perceived perceptual graph model. The mapping process in this case is represented by an *emotive mapping function*, ξ. For DM $k \in N$ define ξ_k as the process that maps all information in the standard graph model into DM *k*'s perceptual graph, written as: $G_k = \xi_k(G)$. Similarly, the emotive mapping function is applied to states ($S_k = \xi_k(S)$), state transitions ($A_i^k = \xi_k(A_i)$), and preferences ($\succeq_i^k = \xi_k(\succeq_i)$). On the other hand, an attentive DM's mapping process may produce an over-perceived graph that contains more states than the standard graph model. Such a DM may be motivated by an urge for vengeance or altruism. For instance, hatred or ignorance motivate a terrorist to perpetrate an atrocity even though its outcome might reasonably be deemed infeasible, while a propitiator will attempt to find innovative states in an effort to bring about rapprochement.

6.3 Stability Analysis of a Graph Model System

6.3.1 General Principles

The first principle of stability analysis is: *a state is stable for a DM if and only if the DM has no incentive to move away from it, should it be attained.* In other words, lack of incentive to move away from a state is necessary and sufficient for it to be stable for a DM. Incentive is determined by calculations that measure the likely success of any effort by the DM to attain a preferred outcome. These calculations reflect the availability of inducements and deterrents. An inducement is a unilateral improvement from the state under investigation, while a deterrent is a sanction which could be levied by an opponent, moving the conflict to an at-best equally preferred state for the focal DM. What constitutes an inducement and a deterrent depends upon the solution concept used.

Some of the requisites that may be incorporated into a stability assessment of a state s for a DM are the following: a state t adjacent to s; departure from s to t must be controlled by the DM; the move from s to t must represent an improvement for the DM (i.e., a unilateral improvement, UI); a deterrent against a UI that could be levied by an opponent (i.e., a sanction); an opponent who prefers to execute the sanction (i.e., its credibility); and the availability of an escape from the sanction. Moreover, a stable state, under a particular solution concept, becomes an equilibrium should the DM also believe that other DMs likewise prefer to stay at that state.

The second principle of stability analysis pertains to the visibility of a state. A state that is inconspicuous to all DMs, though logically valid, must be dropped from the standard graph model. Accordingly, $s \notin S_i$ for all $i \in N$ is equivalent to $s \notin S$. On the other hand, a state that is recognized by a DM and stable for the DM under a particular solution concept in the graph model system must be stable for that DM in the standard graph model under that solution concept. (A mathematical proof for this statement is provided in Section 6.7) Similarly, a state that is recognized and unstable under a particular solution concept for a DM in the graph model system must be unstable in the standard graph model for that DM under that solution concept.

Two important assumptions make it easier to define perceptual solution concepts and carry out meta-stability analysis. First, although no DM knows exactly any other DM's model, and therefore cannot take advantage of this knowledge, a DM may be aware of states in his or her perceptual graph model that are not recognized by other DMs. Second, all DMs recognize the *status quo* state (i.e., $s_0 \in S_i$ for all $i \in N$).

The perceptual graph model of DM k must be built using k's set of *recognized* states, S_k. To avoid trivialities, assume that $S_1 \bigcup S_2 \bigcup ... \bigcup S_n = S$. Note that $S_1 \bigcap S_2 \bigcap ... \bigcap S_n = S^C \neq \emptyset$ because $s_0 \in S^C$. The set S^C is the set of *commonly perceived* states, and $t \in S^C$ means that the state t is recognized by every DM in N. Similarly, define $S_{kj}^C = S_k \bigcap S_j$ to be the set of states *common* to the DMs k and j, and $S_{kj}^P = S_k \bigcap \overline{S}_j$ to be the set of states recognized by k but not j, where $\overline{S}_j$ is the complement of S_j in S. Also, the set of states *private* to DM k is $S_k^P = S_k \cap \overline{S}_1 \cap \overline{S}_2 \cap ... \cap \overline{S}_k \cap \overline{S}_{k+1} \cap ... \cap \overline{S}_n$. If the index of awareness of DM k is $\alpha_k = 0$, then k will not be aware of these private states, i.e., $S_k^P = \varnothing$.

6.3.2 Standard Stability Analysis

A standard graph model provides a convenient formalization for modeling a strategic conflict. It also provides procedures for assessing stability of states, based on various solution concepts (stability definitions) defined within the Graph Model structure. These procedures represent each DM's readiness and strategic approach to behavior in the conflict.

Stability analysis means examining the stability of every state under a particular solution concept for each DM. A solution concept is a set of rules for identifying a state that a DM would stay at, given that the state has been attained. A state that is stable for all DMs in the standard graph model, G, is called an equilibrium, and is considered a predicted resolution for the conflict. Commonly used solution concepts include Nash stability (Nash), general metarationality (GMR), sequential stability (SEQ), and symmetric metarationality (SMR). As discussed in Chapter 2, states that are stable under many solution concepts are usually preferred as they are consistent with a broader range of decision styles and attitudes to risk.

6.3.3 Perceptual Stability Analysis

Stability analysis in the Graph Model methodology is based on the assumption that all decision makers share the same standard graph model. This conventional view becomes inappropriate for perceptual graph models, necessitating a new analysis procedure applicable to graph model systems.

When there are discrepancies in perceptions, conclusions drawn by analyzing a graph model system must depend upon who is doing the analysis (and with what information). Although some DMs may unknowingly share the same perception, it is assumed that each DM's perceptual graph model is private and concealed (i.e., no other DM has knowledge of it), and according to the DM, is the correct representation for the conflict. There is a fundamental requirement, therefore, that whoever does the analysis can use only his or her own information, which consists of perceived states, perceived state transitions, perceived preferences, and any awareness that the analyst may have of states that are inconspicuous to opponents. Hence, each DM sees his or her model as the standard model, which gives the DM a very simple view of other DMs' perceptual graphs (i.e., other graphs are sub-models of the DM's model). By analyzing his or her graph using a particular solution concept, a DM highlights the states that are stable for each DM under that solution concept, which may not be consistent with those identified by other DMs.

The main objective in perceptual stability analysis is to help an *outside* analyst, who will analyze each DM's perceptual graph, from that DM's own point of view, to predict possible resolutions to the conflict. This *outside* analyst will know whether each DM is aware of some states that no other DM knows about, will employ appropriate solution concepts in the analysis, and will consolidate the conclusions of different stability analyses across all perceptual graph models to predict possible resolutions. The underlying structure of perceptual stability analysis is an expansion of the standard stability analysis, and is comprised of the two-phase approach shown in Figure 6.3. In Phase 1, each perceptual graph is analyzed using appropriate solution concepts from the point of view of the DM who owns it, for each DM in the conflict model. Analyzing a perceptual graph is equivalent to treating the DM who owns it as the analyst, but the conclusions drawn by that analyst from applying stability analysis are not alone sufficient to predict a resolution; further analysis is necessary.

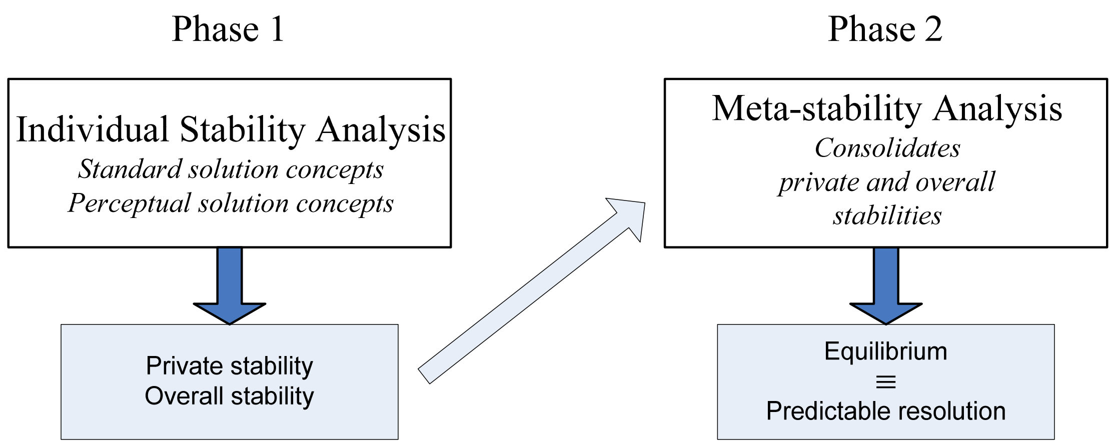


Figure 6.3: Perceptual stability analysis.

The form appropriate for solution concepts in perceptual stability analysis is determined by each DM's index of awareness. On one hand, for example, if DM k is aware that the other DMs recognize only partial views in G_k, i.e., $\alpha_k = 1$, then $G_k \supseteq G_i$ for all $i \in N - k$ and *perceptual solution concepts* (to be defined later) must be used to analyze k's model. If DM k, on the other hand, is unaware of the presence of different graph models to the conflict, i.e., $\alpha_k = 0$, then k believes that $G_k = G_i$ for all $i \in N - k$ and *standard solution concepts* (defined in Chapter 2) must be used to analyze k's model.

In a 2-DM model, let DM i refer to the focal DM who seizes the initiative and moves the conflict to another state, and let i's opponent be DM j. For example, when $k = i$, DM i

analyzes the stability of states in G_i under a particular solution concept twice: first, when *i* is the focal DM while *j* is the opponent, and second, when *j* is the focal DM while *i* is the opponent. The outcomes of DM *i*'s stability analysis represent *i*'s perception of overall and private stabilities of the states in G_i. Similarly, when $k = j$, DM *j* analyzes the stability of the states in G_j for DMs i and j.

In a perceptual graph system, a state that is recognized and stable for all DMs is called overall stable, and is a predicted resolution of the conflict. It is possible for a state to be recognized by some but not all DMs and to be stable for all DMs who recognize it; this means that the state is *pseudo-equilibrium*.

In Phase 2 of Figure 6.3, meta-stability is defined for a graph model system, across all variants of awareness, to predict resolutions using private and overall stabilities. Meta-stability analysis is not performed by any of the DMs but rather by an insightful, *outside* analyst who is aware of incompatibilities in the DMs' models of the conflict. Perceptual graph modeling reflects DMs' perceptions and awareness in the conflict, while perceptual stability analysis permits the exploration of the behavioral consequences of these perceptual differences and leads to insightful conclusions about likely resolutions that reflect inconsistencies in viewpoints.

6.4 Perceptual Solution Concepts—The 2-Decision Maker Case

Perceptual solution concepts for Nash stability, general and symmetric metarationality, and sequential stability are now formulated for the case of perceptual graph models with two DMs. These formulations allow an informed DM to apply appropriate rules that take into account that DM's awareness of the opponent's *limited perception*. Therefore, perceptual solution concepts are employed whenever the owner of a perceptual graph model has an index of awareness equal to one.

As mentioned above, k refers to the DM who owns the perceptual graph model, and either $k = i$ or $k = j$ but not both. For simplicity, assume that $N = \{1, 2\}$. Hence, if $i = 1$ then $j = 2$, and if $i = 2$ then $j = 1$. Furthermore, in perceptual solution concepts, DM k is interested in analyzing states that he or she knows are perceived by the focal DM i, i.e. $s \in S_k \cap S_i$.

Every perceptual graph in the system (G_1, G_2) is a sub-graph that shares some qualities with the standard graph model. Two important features of standard stability analysis are preserved in perceptual stability analysis. First, at any state s, DM i can identify two subsets within S: $\Phi_i^+(s) = \{s_m : s_m \succ_i s\}$ is the set of all states that DM i prefers to s, and $\Phi_i^{\leq}(s) = \{s_m : s_m \preceq_i s\}$ is the set of all states that DM i finds equally or less preferred to s. Second, DM i's *reachable list* $R_i(s)$ from state s is the set of all states that can be reached by DM i in one step from state s. The concept of *unilateral improvement* is based upon these two features. A unilateral improvement (UI) from a particular state for a specific DM is a preferred state for that DM to which he or she can unilaterally move in one step. Therefore, $R_i(s)$ can be divided into two sets: $R_i^+(s) = R_i(s) \cap \Phi_i^+(s)$ represents the *set of all unilateral improvements* from state s for DM i, and $R_i^{\leq}(s) = R_i(s) \cap \Phi_i^{\leq}(s)$ represents the *set of all unilateral disimprovements* from state s for DM i, where moving to an equally preferred state is considered to be a disimprovement since nothing is gained.

6.4.1 Perceived Default Stability

The analysis of a perceptual graph model G_k, which is done from the point of view of DM k (the owner), must first distinguish between two kinds of stability of a state for a focal DM: 1) the state is stable because the DM cannot unilaterally move away from it, and 2) the state is stable because, although the DM can move away from it, the DM has no incentive to do so. The former stability is described as *stability by default*.

Definition 6.4.1.a: Perceived default stability

For $i \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by k to be default stable for DM i if and only if (iff) there exists no unilateral move from s for i, i.e., $R_i(s) \cap S_k = \emptyset$.

Default stability describes the situation where the focal DM i has no option but to accept the current state because there exists no adjacent state that i can move to. Note that DM k assesses the reachable list, $R_i(s)$, for the focal DM i that is located in S_k. A special case occurs when DM k is aware of some adjacent states that are invisible to focal DM i. Hence, k knows that the current state appears to be default stable for DM i, although in reality it is not.

Definition 6.4.1.b: Apparent default stability

For $i \in N$, a state $s \in S^C$ is perceived by *j* to be an apparently default stable for DM i iff all unilateral moves away from *s* are inconspicuous to *i*, i.e., $R_i(s) \cap S^C = \varnothing$ and $R_i(s) \cap S_j^P \neq \varnothing$.

Apparent default stability reflects the *limited perception* of a focal DM; all states reachable from the current state are in *j*'s *privately perceived* set of states, S_j^P. If the focal DM were to become aware of these adjacent states, the current state would be assessed for stability under other solution concepts.

6.4.2 Perceived Nash Stability

Nash stability describes a rational (though shortsighted) DM who makes choices conducive to his or her best interest. According to Luce and Raiffa (1957, p. 50): "of two alternatives which give rise to states, a player will choose the one which yields the more preferred state." A reformulated Nash stability definition must take into account a DM's inability to recognize the more preferred state. Let $S_k^{\text{Nash}_i}$ denote the set of states in S_k that are perceived to be Nash stable for focal DM *i*.

Definition 6.4.2.a: Perceived Nash stability

For $i \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by *k* to be Nash stable for DM *i*, denoted by $s \in S_k^{\text{Nash}_i}$, iff $R_i(s) \cap S_k \cap S_i \neq \varnothing$ and $R_i^+(s) \cap S_k = \varnothing$.

In this definition, DM k investigates UIs (i.e., $R_i^+(s)$) for the focal DM i that are located in k's perceptual graph model. DM k perceives a state to be Nash stable for the focal DM i whenever k believes that there is no preferred state in S_k that i can move to; without regard to any possible countermoves by the opponent. Note that $R_i(s) \cap S_k \neq \varnothing$ is implied by $R_i(s) \cap S_k \cap S_i \neq \varnothing$, so state s is neither perceived default nor apparently default stable, while the condition $R_i^+(s) \cap S_k = \varnothing$ ensures that there are no UIs for the focal DM i in S_k. As a special case, a state that is not Nash stable in the standard graph model may be apparently Nash stable in the opponent's perceptual graph model if all the UIs are located in the opponent's *privately perceived* set of states. Once the focal DM becomes aware of these UIs, the state no longer remains Nash stable. Let $S_j^{\text{ANash}_i}$ denote the set of states in S_j that are perceived to be apparently Nash stable for focal DM i.

Definition 6.4.2.b: Apparent Nash stability

For $i \in N$, a state $s \in S^C$ is perceived by j to be apparently Nash stable for DM i, denoted by $s \in S_j^{\text{ANash}_i}$, iff $R_i(s) \cap S^C \neq \varnothing$ and $R_i^+(s) \cap S^C = \varnothing$, but $R_i^+(s) \cap S_j^P \neq \varnothing$.

Although DM i can move unilaterally from the current state, all UIs are apprehended by DM j but not by the focal DM i whose perception is limited. Note that apparent Nash stability does not apply to the focal DM who owns the graph model, i.e., $k = i$, since DM i's awareness would be equal to DM k's. Therefore, apparent stability applies only for a focal DM with limited perception.

The definitions of GMR, SEQ, and SMR stabilities require the presence of some UIs from current state. Therefore, a state that is Nash stable or apparently Nash stable for a DM is, by definition, GMR, SEQ, and SMR stable (see below).

6.4.3 Perceived General Metarationality Stability

Howard (1971) modeled the behavior of a cautious DM who is tempted to move to a more preferred state but considers all possible damaging reactions by the opponent (sanctions). The DM contemplates exactly two steps ahead and does not think of escaping any sanctions. Let $S_k^{\mathrm{GMR}_i}$ denote the set of states in S_k that are perceived to be apparently GMR stable for focal DM *i*.

Definition 6.4.3.a: Perceived General Metarationality

For $i, j \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by *k* to be GMR stable for DM *i*, denoted by $s \in S_k^{\mathrm{GMR}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and for every $t \in R_i^+(s) \cap S^C$ there exists $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \varnothing$.

Thus, DM k perceives a state to be GMR stable for the focal DM i whenever k believes that if i takes advantage of any available UI, DM *j* can sanction this UI (i.e., $R_j(t) \cap \Phi_i^{\leq}(s)$) and will do so irrespective of whether it is in *j*'s interest to do so. In Definition 6.4.3.a., the set of states common to both the focal DM and the opponent must be perceived by the owner of the perceptual graph model. For example, setting $k = i$, a simplified form of perceived GMR stability is obtained: *For* $i, j \in N$, *a state* $s \in S_i$ *is perceived by i to be GMR stable* *for DM i, denoted by* $s \in S_i^{\mathrm{GMR}_i}$, *iff* $R_i^+(s) \cap S^C \neq \varnothing$ *and for every* $t \in R_i^+(s) \cap S^C$ *there exists* $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \varnothing$.

To assess perceived GMR stability, DM k investigates UIs and sanctions in G_k that are recognized by both the focal DM and his or her opponent (if $k = i$, it is not necessary that the state s be recognized by the opponent). Consequently, a GMR stable state for a focal DM in a standard graph model will be stable in a perceptual graph model for that DM if and only if all UIs and, for each UI, some possible sanction belongs to the set of states *common* to the DMs.

Moreover, depending on who owns the perceptual graph model (i.e., $k = i$ or $k = j$), a GMR stable state for a focal DM in a standard graph may be perceived as *GMR unstable* in the perceptual graph model for the focal DM. Specifically, if $k = i$ and DM i has a UI that is *privately perceived* by i (i.e., S_i^P), or the UI is commonly visible to both DMs but every sanction by DM j belongs to S_i^P, then the state must be perceived as *GMR strategic advantage unstable* for DM i. Consequently, the focal DM i may take advantage of the UI, which would not be the case in the standard graph model under the GMR solution concept. On the other hand, if $k = j$ and a sanction for DM i's UI is not recognized by i (i.e., a UI belongs to S_j^P), then the focal state must be perceived by DM j to be *GMR strategic disadvantage unstable* for DM i. The focal DM i may take advantage of the available UI, unaware of the opponent's inconspicuous sanction. Formally, the two strategic instabilities are defined as follows:

Definition 6.4.3.b: GMR strategic advantage instability

For $i, j \in N$, a state $s \in S_i$ is perceived by *i* to be GMR strategic advantage unstable for DM *i*, denoted by $s \in S_i^{\text{GSAUN}_i}$, iff $R_i^+(s) \cap S_i^P \neq \varnothing$ or $R_i^+(s) \cap S^C \neq \varnothing$ and there exists $t \in R_i^+(s) \cap S^C$ such that $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C = \varnothing$ but $R_j(t) \cap \Phi_i^{\leq}(s) \cap S_i^P \neq \varnothing$.

In definition 6.4.3.b, $S_i^{\text{GSAUN}_i}$ denotes the set of states in S_i that are perceived to be GMR strategic advantage unstable for focal DM *i*. Strategic advantage instability reflects the opponent's *limited perception* of the focal DM's UIs or the sanctions to a UI. If the focal DM *i* takes advantage of an available UI, the opponent will discover some of the hidden states; a new graph model that takes into account this disclosure will become necessary.

Definition 6.4.3.c: GMR strategic disadvantage instability

For $i, j \in N$, a state $s \in S^C$ is perceived by *j* to be GMR strategic disadvantage unstable for DM *i*, denoted by $s \in S_j^{\text{GSDUN}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and there exists $t \in R_i^+(s) \cap S^C$ such that $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C = \varnothing$ but $R_j(t) \cap \Phi_i^{\leq}(s) \cap S_j^P \neq \varnothing$.

In definition 6.4.3.c, $S_j^{\text{GSDUN}_i}$ denotes the set of states in S_j that are perceived to be GMR strategic disadvantage unstable for focal DM *i*. Strategic disadvantage instability is "blindsided" GMR stability, ultimately caused by the focal DM's *lack of perception* of the opponent's sanction. Thus, in G_j, DM *j* has sanctions to some of DM *i*'s UIs that are inconspicuous to DM *i*.

A state that is stable in a standard graph model for a DM may become strategically unstable for the DM in a graph model system in either DMs' perception. A state that is strategically unstable highlights the value of knowledge in a graph model system and gives the DM with the knowledge an edge over the opponent.

6.4.4 Perceived Sequential Stability

Fraser and Hipel (1984) modified Howard's (1971) general metarationality definition to define sequential stability (SEQ) by considering only sanctions that are unilateral improvements for the sanctioner (called "credible sanctions"). Similar to GMR, in SEQ stability a DM contemplates exactly two steps ahead and does not ask whether sanctions can be circumvented. Let $S_k^{\mathrm{SEQ}_i}$ denote the set of states in S_k that are perceived to be SEQ stable for focal DM *i*.

Definition 6.4.4.a: Perceived sequential stability

For $i, j \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by *k* to be SEQ stable for DM *i*, denoted by $s \in S_k^{\mathrm{SEQ}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and for every $t \in R_i^+(s) \cap S^C$ there exists $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \varnothing$.

Thus, DM k perceives a state to be SEQ stable for the focal DM i when *k* believes that, if *i* takes advantage of any possible UI, DM j has a credible sanction (i.e., a state in $R_j^+(t) \cap \Phi_i^{\leq}(s)$). DM *k* investigates UIs and credible sanctions that are recognized by both the focal DM and his or her opponent in G_k (if $k = i$, it is not necessary that the state *s* be recognized by the opponent). Consequently, a SEQ stable state for a focal DM in a standard graph model will be stable in a perceptual graph model for that DM if and only if all the UIs and some possible credible sanctions belong to the set of states *common* to the DMs. For example, setting $k = j$, a simplified form of perceived SEQ stability is obtained: *For $i \in N$, a state $s \in S^C$ is perceived by j to be SEQ stable for DM i, denoted by $s \in S_j^{\mathrm{SEQ}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and for every $t \in R_i^+(s) \cap S^C$ there exists $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \varnothing$.*

Since the underlying rules in SEQ and GMR stabilities are similar, the definitions of GMR strategic advantage unstable and GMR strategic disadvantage unstable can be extended readily to SEQ stability.

Definition 6.4.4.b: SEQ strategic advantage instability

For $i, j \in N$, a state $s \in S_i$ is perceived by *i* to be SEQ strategic advantage unstable for DM *i*, denoted by $s \in S_i^{\mathrm{QSAUN}_i}$, iff $R_i^+(s) \cap S_i^P \neq \varnothing$ or $R_i^+(s) \cap S^C \neq \varnothing$ and there exists $t \in R_i^+(s) \cap S^C$ such that $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S^C = \varnothing$ but $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S_i^P \neq \varnothing$.

In definition 6.4.4.b, $S_i^{\mathrm{QSAUN}_i}$ denotes the set of states in S_i that are perceived to be SEQ strategic advantage unstable for focal DM *i*. Thus, a state is perceived by focal DM *i* to be SEQ SAUN if i has a UI that is privately perceived, or the UI is commonly perceived by both DMs but every credible sanction by the opponent *j* belongs to S_i^P. Notice that by definition if a state has a privately perceived UI, the state is both GMR and SMR strategic advantage unstable for the focal DM who owns the perceptual graph model.

Definition 6.4.4.c: SEQ strategic disadvantage instability

For $i, j \in N$, a state $s \in S^C$ is perceived by *j* to be SEQ strategic disadvantage unstable for DM *i*, denoted by $s \in S_j^{\text{QSDUN}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and there exists $t \in R_i^+(s) \cap S^C$ such that $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S^C = \varnothing$ but $R_j^+(t) \cap \Phi_i^{\leq}(s) \cap S_j^P \neq \varnothing$.

In definition 6.4.4.c, $S_j^{\text{QSDUN}_i}$ denotes the set of states in S_j that are perceived to be SEQ strategic disadvantage unstable for focal DM *i*. A state must be perceived by DM *j* to be SEQ strategic disadvantage unstable for focal DM *i* if *j* has a credible sanction for *i*'s UI in S_j^P.

6.4.5 Perceived Symmetric Metarationality Stability

Howard (1971) extended general metarationality to symmetric metarationality (SMR). Under SMR stability, a focal DM considers not only the initial improvement (UI) and the sanctions by the opponent, but also his or her possible escape from such sanctions. A state that is GMR stable will be assessed for SMR stability. Therefore, a DM contemplates exactly three steps ahead, including escaping from any sanction that may be imposed by the opponent. Let $S_k^{\text{SMR}_i}$ denote the set of states in S_k that are perceived to be SMR stable for focal DM *i*.

Definition 6.4.5.a: Perceived symmetric metarationality

For $i, j \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by *k* to be SMR stable for DM *i*, denoted by $s \in S_k^{\text{SMR}_i}$, iff $R_i^+(s) \cap S^C \neq \varnothing$ and for every $t \in R_i^+(s) \cap S^C$, $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \varnothing$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C$, $R_i(h) \cap \Phi_i^+(s) \cap S_k = \varnothing$.

Thus, DM *k* perceives a state to be SMR stable for the focal DM *i* whenever *k* believes that if *i* takes advantage of any possible UI, DM *j* has an inescapable sanction. An inescapable sanction is a sanction from which the focal DM has no counter-response to move to a state that is preferable to the original state. Note that SMR stability is a strengthening of GMR stability. However, it is necessary that all escapes be recognized by DM *k*. For example, setting $k = j$, a simplified form of perceived SMR stability definition is obtained: *For* $i, j \in N$, *a state* $s \in S^C$ *is perceived by j to be SMR stable for DM i, denoted by* $s \in S_i^{\mathrm{SMR}_i}$, *iff* $R_i^+(s) \cap S^C \neq \emptyset$ *and for every* $t \in R_i^+(s) \cap S^C$, $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \emptyset$, *and for all* $h \in R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C$, $R_i(h) \cap \Phi_i^{+}(s) \cap S_j = \emptyset$.

A state that is not SMR stable for the focal DM in the standard graph model may be apparently SMR stable in the opponent's perceptual graph model if all escapes to sanctions are located in the opponent's *privately perceived* set of states. Once the focal DM becomes aware of these escapes, the state no longer remains SMR stable.

Definition 6.4.5.b: Apparent symmetric metarationality stability

For $i, j \in N$, a state $s \in S^C$ is perceived by *j* to be apparently SMR stable for DM *i*, denoted by $s \in S_j^{\mathrm{ASMR}_i}$, iff $R_i^+(s) \cap S^C \neq \emptyset$ and for every $t \in R_i^+(s) \cap S^C$, $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \emptyset$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C$, $R_i(h) \cap \Phi_i^{\leq}(s) \cap S^C = \emptyset$ but $R_i(h) \cap \Phi_i^{+}(s) \cap S_j^P \neq \emptyset$.

In definition 6.4.5.b, $S_j^{\mathrm{ASMR}_i}$ denotes the set of states in S_j that are perceived to be apparently SMR stable for focal DM *i*. According to this definition, all escapes are apprehended by DM *j* but not by the focal DM *i* with *limited perception*. Similar to apparent Nash stability, apparent SMR does not apply for the focal DM who owns the graph model. Therefore, apparent SMR stability must be only used for a focal DM with limited perception. For example, setting $k = i$, the apparently SMR stability definition does not apply since DM i is endowed with awareness.

6.5 Meta-Stability Analysis

6.5.1 Variants of Awareness

Meta-stability analysis is performed by an analyst, who is aware of the inconsistencies in the DMs' perceptions, and can analyze each perceptual graph model in a graph model system from the point of view of its owner. In a graph model system, different DMs generally have different comprehensions of the same conflict, albeit they may agree on some features. So it becomes important to keep track of which perceptual graph model is being analyzed and what each DM knows. Consequently, a perceptual graph model expresses each DM's perception of the conflict, and each DM's viewpoint, which reflects the awareness of states that are inconspicuous to other DMs.

A graph model system, therefore, includes a *viewpoint* for every DM. A viewpoint is the perspective used by a DM in viewing and analyzing the conflict and it reflects the DM's awareness of other DMs' perceptions. DM k's viewpoint marks those states in G_k which are shared with other DMs, and it partitions k's set of recognized states S_k according to recognition by the opponents. Hence, if $\alpha_k = 0$, DM k's viewpoint is S_k such that $S_k = S_i^k$

for all $i \in N$; whereas if $\alpha_k = 1$, DM k's viewpoint is $S^C \cap S_k^P$ such that $S_k \supseteq S_i^k$ for all $i \in N$.

Consolidating individual stability analysis in a graph model system requires considering all combinations of each DM's two possible viewpoints. In a 2-DM model, the set of ordered combinations of DMs' viewpoints defines the *variant of awareness*, (α_i, α_j), which corresponds to a specific graph model system.

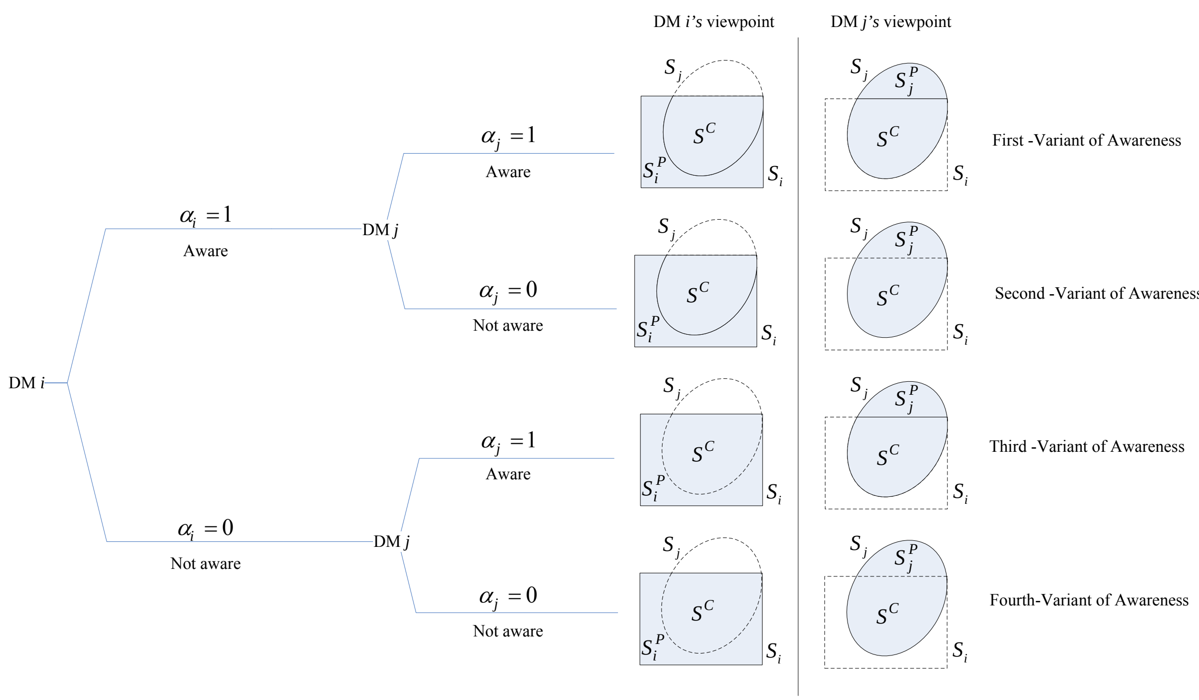


Figure 6.4: Variants of awareness for a 2-decision maker conflict.

Figure 6.4 shows a system of two perceptual graph models for each variant of awareness. The owner of each perceptual graph model in the first-variant of awareness, $(\alpha_i, \alpha_j) = (1,1)$, is aware of the states that are inconspicuous to the other DM. From DM i's viewpoint, the dashed-line encloses the subset in S_j that is not perceived by i, who recognizes the grey rectangle S_i, and can distinguish the privately perceived states, in S_i^P, from the commonly perceived states, in S^C.

Similarly, from DM *j*'s viewpoint, the dashed-line signifies the subset of S_i that is not perceived by DM *j*, who can distinguish the privately perceived states, in S_j^P, from the commonly perceived states, in S^C. Only one of the owners in the second and third -variants is aware of states in his or her own perceptual graph model that are invisible to the other DM. In the fourth-variant, both DMs are unaware that they are viewing different graph models. On the other hand, the *real* analyst is aware of all sets and subsets of perceptual graph models, regardless of the variant of awareness.

6.5.2 Applying Perceptual Stability Analyses

A DM's viewpoint specifies the set of recognized states, and indicates whether the DM can distinguish commonly from privately perceived states. An informed DM is able to recognize privately and commonly perceived states in his or her perceptual graph model, while an unaware DM believes there is only one standard graph model and does not recognize that some states are not perceived by the opponent.

Whatever the variant of awareness, perceptual stability analyses are applied to a graph model system by examining the stability of perceived states for all DMs in every perceptual graph, from the viewpoint of the DM who owns it. The appropriate form of each solution concept depends on the DM's awareness. In a 2-DM model, when $k = i$ analyzes G_i from *i*'s viewpoint, *standard solution concepts* should be used if $\alpha_i = 0$ and *perceptual solution concepts* should be used if $\alpha_i = 1$. Similarly, for $k = j$.

Table 6.1 illustrates how perceptual stability analyses are applied for a 2-DM model. No analysis is performed in the cells labeled "A" because the owner of the perceptual graph model does not recognize the set of states privately perceived by the other DM. For example, in DM *i*'s perceptual graph model, *i* does not recognize the set S_j^P. Furthermore, the cells labeled "B" or "C" indicate that the owner of a perceptual graph model is aware that his or her privately perceived states are not recognized by the other DM, and therefore no analysis is performed on these states for that DM. For example, if $\alpha_i = 1$, DM i knows that DM *j* does not recognize states in S_i^P. DM *i*, therefore, will not analyze any state in S_i^P for focal DM j. Similarly, if $\alpha_j = 1$, DM j will not analyze states in S_j^P for the focal DM *i*.

Table 6.1: Template for a 2-DM Model Perceptual Stability Analysis

<table>
<tr><th>(α_i, α_j)</th><th></th><th colspan="8">$k = i$</th><th colspan="8">$k = j$</th></tr>
<tr><td rowspan="6">(1,1)</td><td rowspan="3"></td><td colspan="8">$[G_i, \ \alpha_i = 1]$</td><td colspan="8">$[G_j, \ \alpha_j = 1]$</td></tr>
<tr><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td><td colspan="4">Focal DM 1</td><td colspan="4">Focal DM2</td></tr>
<tr><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td></tr>
<tr><td>S^C</td><td colspan="8">[Analyze using perceptual solution concepts]</td><td colspan="8">[Analyze using perceptual solution concepts]</td></tr>
<tr><td>S_i^P</td><td colspan="4">[Analyze using perceptual solution concepts for private stability]</td><td colspan="4">B</td><td colspan="8">A</td></tr>
<tr><td>S_j^P</td><td colspan="8">A</td><td colspan="4">C</td><td colspan="4">[Analyze using perceptual solution concepts for private stability]</td></tr>
<tr><td rowspan="6">(1,0)</td><td rowspan="3"></td><td colspan="8">$[G_i, \ \alpha_i = 1]$</td><td colspan="8">$[G_j, \ \alpha_j = 0]$</td></tr>
<tr><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td></tr>
<tr><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td></tr>
<tr><td>S^C</td><td colspan="8">[Analyze using perceptual solution concepts]</td><td colspan="8">[Analyze using standard solution concepts]</td></tr>
<tr><td>S_i^P</td><td colspan="4">[Analyze using perceptual solution concepts for private stability]</td><td colspan="4">B</td><td colspan="8">A</td></tr>
<tr><td>S_j^P</td><td colspan="8">A</td><td colspan="8">[Analyze using standard solution concepts]</td></tr>
<tr><td rowspan="6">(0,1)</td><td rowspan="3"></td><td colspan="8">$[G_i, \ \alpha_i = 0]$</td><td colspan="8">$\{G_j, \ \alpha_j = 1]$</td></tr>
<tr><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td></tr>
<tr><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td></tr>
<tr><td>S^C</td><td colspan="8">[Analyze using standard solution concepts]</td><td colspan="8">[Analyze using perceptual solution concepts]</td></tr>
<tr><td>S_i^P</td><td colspan="8">[Analyze using standard solution concepts]</td><td colspan="8">A</td></tr>
<tr><td>S_j^P</td><td colspan="8">A</td><td colspan="4">C</td><td colspan="4">[Analyze using perceptual solution concepts for private stability]</td></tr>
<tr><td rowspan="6">(0,0)</td><td rowspan="3"></td><td colspan="8">$[G_i, \ \alpha_i = 0]$</td><td colspan="8">$[G_j, \ \alpha_j = 0]$</td></tr>
<tr><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td><td colspan="4">Focal DM i</td><td colspan="4">Focal DM j</td></tr>
<tr><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td><td>Nash</td><td>GMR</td><td>SMR</td><td>SEQ</td></tr>
<tr><td>S^C</td><td colspan="8">[Analyze using standard solution concepts]</td><td colspan="8">[Analyze using standard solution concepts]</td></tr>
<tr><td>S_i^P</td><td colspan="8">[Analyze using standard solution concepts]</td><td colspan="8">A</td></tr>
<tr><td>S_j^P</td><td colspan="8">A</td><td colspan="8">[Analyze using standard solution concepts]</td></tr>
</table>

6.5.3 Overall and Private Stabilities

It must be emphasized that the outcomes of perceptual stability analysis depend on the awareness of the owner of the graph model and the location of the assessed state for stability. Figure 6.5 shows the different outcomes that can be obtained under a particular solution concept in analyzing DM *k*'s perceptual graph model. A state that is recognized by DM *k* and stable for all DMs is an *overall stable* state from the viewpoint of DM *k*. Formally:

Definition 6.5.3.a: Overall stability

A state $s \in S_k$ is overall stable for DM $k \in N$ under a particular solution concept iff s is stable for all DMs in *k*'s perceptual graph model.

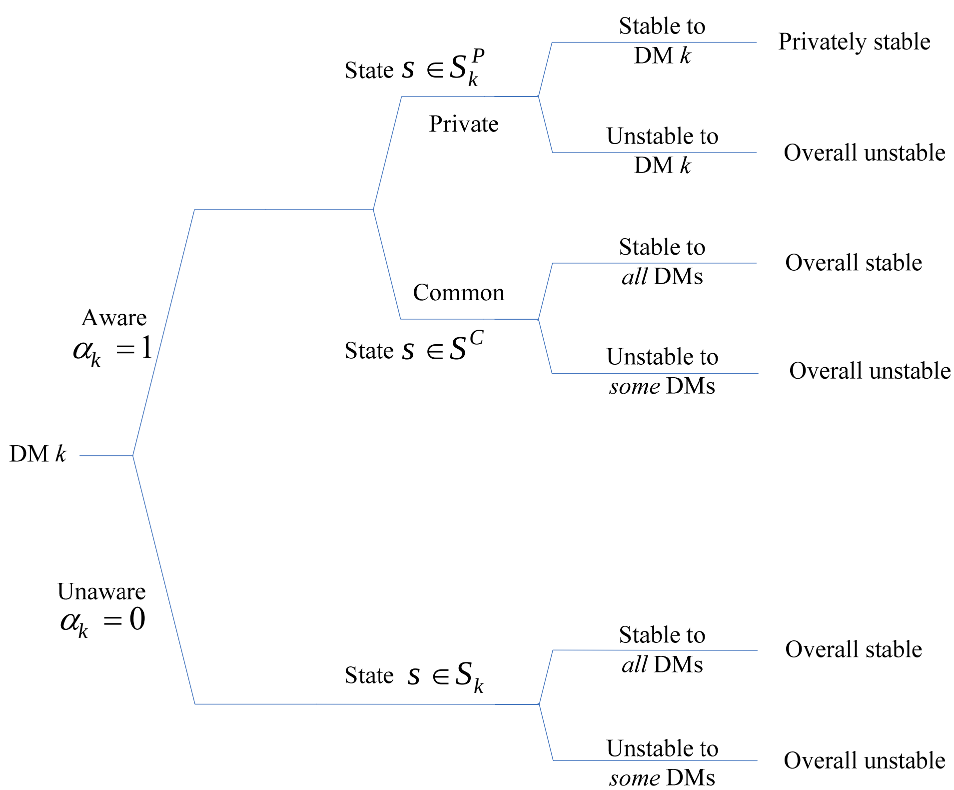


Figure 6.5: The outcomes of perceptual stability analysis.

Equilibrium and overall stability are synonyms in a standard graph model as they both refer to a state that is stable for all DMs under a particular solution concept. No assumptions are made yet about the visibility of the state to any DM in *k*'s perceptual graph model. But, as shown in Figure 6.5, if $\alpha_k = 1$, then state *s* is overall stable in G_k if it belongs to the set of commonly perceived states, i.e, $s \in S^C$, and *s* is stable for both DMs, while if $\alpha_k = 0$, there is no restriction on the location of state *s* in G_k. On the other hand, if DM *k* is aware that a state in S_k is not recognized by other DMs and the state is stable for focal DM *k* only, then it is described as being *privately stable* for *k*. Formally:

Definition 6.5.3.b: Private stability

A state $s \in S_k$ is privately stable for DM $k \in N$ under a particular solution concept iff $\alpha_k = 1$, $s \in S_k^P$ and s is stable for *k* under that solution concept.

6.5.4 Meta-stability Analysis Technique

Perceptual stability analysis requires examining the stability of a state in all graph models. Nonetheless, overall (or private) stability in a DM's perceptual graph model under a particular solution concept is not sufficient to qualify the state to be an equilibrium under that solution concept, and thereby is not a predicted resolution to conflict. Hence, new definitions suitable to incompatibilities in DMs' perceptions and viewpoints and capable of providing important insights into the robustness of stability and the sustainability of particular resolutions must be introduced.

An equilibrium has to be determined by consolidating each of the DMs' stability analysis conclusions, and indicates a common belief among all DMs of a commensurable, predictable resolution. An *outside* analyst, therefore, must employ meta-stability analysis on all states that are perceived to be stable in a perceptual graph system. Meta-stability is determined by first, examining the stability of states *across* all graphs in a perceptual graph model system and, second, examining equilibrium states *across* all variants of awareness.

To begin with, an equilibrium as a predicted resolution to conflict should take into account both the perceptibility and stability of a state. Consequently, a state must be recognized and be overall stable from the point of view of each DM in order to be an equilibrium. Formally:

Definition 6.5.4.a: Equilibrium

A state $s \in S$ is an equilibrium under a particular solution concept iff for every $i \in N$, $s \in S_i$ and s is overall stable for DM *i* under that solution concept.

For a state to be an equilibrium, it must belong to the set of commonly perceived states S^C and be overall stable in every perceptual graph model. Accordingly, a state that is recognized by all DMs in a perceptual graph system but *not overall stable* in at least one perceptual graph model is not an equilibrium. On the other hand, if a state is not recognized by all DMs, but it is overall stable for all the DMs who recognize it, then the state is a *pseudo-equilibrium*. Formally:

Definition 6.5.4.b: Pseudo-equilibrium

A state $s \in S$ is a pseudo-equilibrium under a particular solution concept iff s is overall stable for every DM *i* such that $s \in S_i$ for some but not all $i \in N$.

For instance in a 2-DM model, if a state is recognized and overall stable in DM 1's perceptual graph model and is not recognized by DM 2, then the state is a pseudo-equilibrium. A pseudo-equilibrium state is an illusionary equilibrium in that some DMs recognize it and find it overall stable, but it is unsustainable because some DMs do not perceive it as a possible outcome. However, if the DMs who recognize a pseudo-equilibrium state attain and choose to stay at it, it will become a status quo, and thereby will become recognizable to all DMs and part of all perceptual graph models. Presumably, a new model, and new perceptual stability and meta-stability analyses will be appropriate at this point. Thus, it is reasonable to expect that a pseudo-equilibrium will be stable at least in the short term, until all DMs adjust their models to account for it, and may be stable in the long term depending on those adjusted models.

DM *k*'s awareness that other DMs do not perceive some states in *k*'s perceptual graph model qualifies states that are privately perceived to be stable by *k* as private equilibria. Therefore, a state $s \in S$ is a private equilibrium for $k \in N$ under a particular solution concept iff $s \in S_k^P$ and s is privately stable for DM k under that solution concept. Accordingly, a private equilibrium is a special case of pseudo-equilibrium, occurring when a DM is aware that other DMs have different perceptual graph models for a conflict. A private equilibrium results from others' limited perceptions while pseudo-equilibrium results from all DMs' limited perceptions—the former reflects awareness while the latter does not.

Since an *outside* analyst may be interested in comparing the consequences of different variants of awareness, it is necessary to gauge the *sustainability* of any resolution in a graph model system. The *sustainability* of a resolution is an *assessment of the robustness* of perceptual stability analysis to changes in each DM's awareness of other DMs' models. The next step in meta-stability analysis, therefore, is to examine the equilibrium of states *across* all variants of awareness. Figure 6.6 shows the overall stability of a state, under a particular solution concept, across perceptual graph models and variants of awareness.

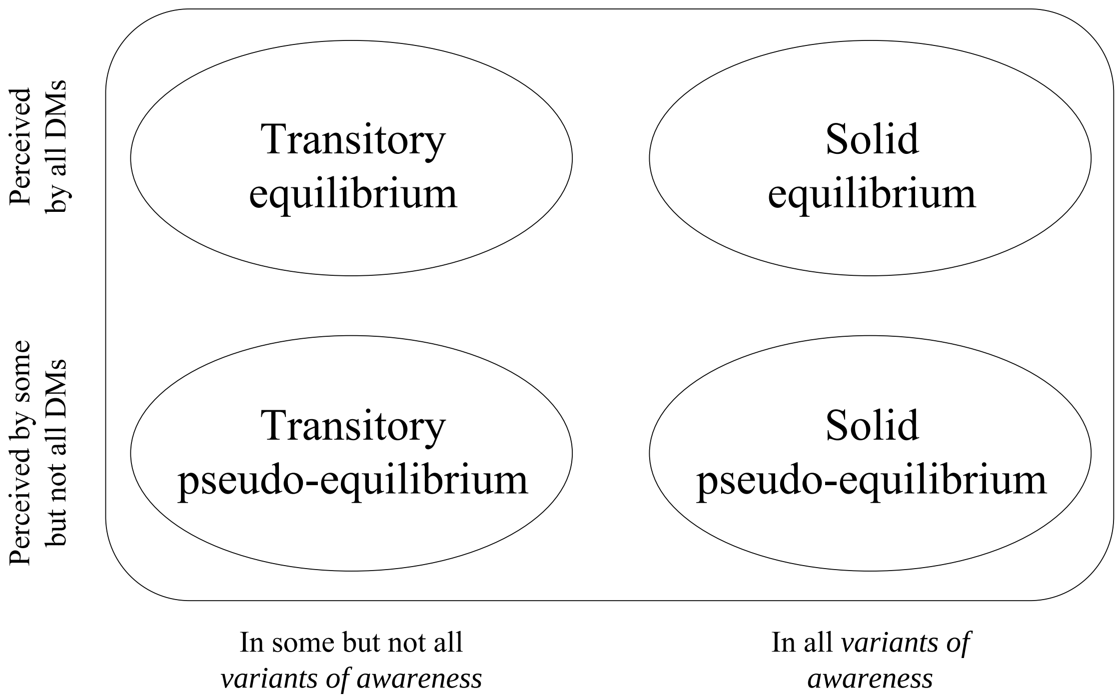


Figure 6.6: Properties of equilibrium as a function of perceptual graphs and variants of awareness.

The equilibrium (or pseudo-equilibrium) of a state under a particular solution concept can be either *solid* or *transitory*, depending on whether the state is consistently an equilibrium in all, or only some, variants of awareness. A state that is a solid equilibrium across all variants of awareness is a credible predicted resolution, independent of every DM's awareness. The persistence of an equilibrium across all variants of awareness imbues it with credibility and sustainability as a potential resolution to the conflict, once it is attained. In a 2-DM model, a state that is an equilibrium across the four variants of awareness in a perceptual graph system is a solid equilibrium. Formally:

Definition 6.5.4.c: Solid equilibrium

A state $s \in S$ is a solid equilibrium under a particular solution concept iff s is an equilibrium in all variants of awareness in a perceptual graph system.

Likewise, a state that is a pseudo-equilibrium across all variants of awareness is a *solid pseudo-equilibrium* state, which means that the state is overall stable in some but not all perceptual graph models, independent of the DM's index of awareness, and not recognized by the other DMs. On the other hand, an equilibrium (or pseudo-equilibrium) may prevail in some but not all variants of awareness. Whether the state qualifies as a predicted resolution should it be attained depends on the awareness of the DMs. Formally:

Definition 6.5.4.d: Transitory equilibrium

A state $s \in S$ is a transitory equilibrium under a particular solution concept iff s is an equilibrium in some but not all variants of awareness.

In a 2-DM model, a state that is an equilibrium in some but not all variants of awareness and is overall stable in other variants for only one of the DMs is a transitory equilibrium. In other words, the state is a predicted resolution because it is overall stable in some variants of awareness for all DMs but is not a predicted resolution in other variants of awareness, because it is perceived and overall stable in only some of the graph models.

A state that is a pseudo-equilibrium in some but not all variants of awareness is a transitory pseudo-equilibrium state. Formally:

Definition 6.5.4.e: Transitory pseudo-equilibrium
A state $s \in S$ is a transitory pseudo-equilibrium iff s is pseudo-equilibrium across some but not all variants of awareness.

If the equilibrium of a state is conditional on some DM's awareness, the equilibrium is precarious, and the analyst should seek further information about that awareness before making a prediction. Furthermore, if a transitory equilibrium or pseudo-equilibrium state is a desired outcome, one must employ appropriate strategies to ensure that the state is perceived by all DMs to make it a solid equilibrium.

The 1990s confrontation in Chechnya between Russia and Chechen Rebels, an emotion-laden struggle with inconsistent perceptions, is used to illustrate perceptual stability analysis approach.

6.6 The Chechnya Conflict

For almost two centuries since the expansion of the Tsarist Empire through the Caucasus region, the Chechens have fought fiercely for their independence, and have suffered a great deal as a consequence. One of the greatest atrocities was the mass deportation of the Chechen and Ingush people to Kazakhstan and Siberia ordered by Stalin in 1944, apparently caused by his suspicion that they were collaborating with Nazi Germany (Eide, 2001). With the collapse of the Soviet Union in 1991, Dzhokhar Dudayev, Chechnya's former leader, declared the unilateral independence of Chechnya from the Russian Federation. When the Russian army invaded Chechnya in 1994, its stated objective was to bring civil obedience and order to this autonomous Russian Republic (Sirén, 1998). To Moscow's surprise, a long and brutal war ensued. The Chechen fighters fought the Russian army to a draw, and in 1996 both sides agreed to postpone a decision about Chechnya's status until 2001. In December 1996, Russian forces were withdrawn from Chechnya.

Chechen leaders behaved as if the peace agreement with Moscow endowed them with a *de facto* legitimacy. They called an election in 1997, and Aslan Maskhodov was declared the first President of Chechnya. However, Maskhadov's uneasy alliance with Chechen radical leaders Shamil Basaev and Amir Khattab undermined his authority and encouraged Islamic militants from Afghanistan and central Asia to enter Chechnya. Maskhodov's authority weakened, and in February 1999 he was forced to adopt *Sharia law* (Evangelista, 2002). Six months later, purportedly to establish an Islamic state, Chechen extremists who followed Basaev and Khattab invaded the neighboring Russian republic of Dagestan, unleashing a wave of terror in Chechnya, Dagestan, and elsewhere. Maskhadov's reluctance to capture Basaev and Khattab, destroy rebel bases in the mountains, and send Chechen troops to Dagestan angered the Russian government, which accused him of harboring militants, including the terrorists responsible for explosions in apartment buildings in Moscow (Evangelista, 2002). In September 1999, Russia officially launched a second military campaign to establish a "security zone" in Chechnya, terminating all diplomatic contacts with Maskhadov. Since then, there have been thousands of civilian casualties on both sides;

terrorism has continued in Russian cities; and Russian armies have been accused of brutal and indiscriminate killings to root out rebels from villages. After the terrorist attacks on the United States in 2001, the Russian government justified its campaign in Chechnya as part of the global war against terrorism (Demitri and Malashenko, 2004).

To supplant Maskhadov, a pro-Russian government headed by Akhmad Kadyrov was established in Grozny. In March 2003, Chechens voted by referendum to abandon complete independence in favor of maintaining Chechnya as an autonomous republic within Russia. In return, they expected peace. However, suicide bombings and terrorism continue, including the 2004 attack on a school in Beslan, North Ossetia, in which hundreds of children were killed.

6.6.1 The Standard Graph Model for the Chechnya Conflict

To illustrate the analysis, the focus will be on a simplified version of the conflict in Chechnya, with only two DMs: Russia and Chechen Rebels (who encompass Chechen separatists and extremists). As of January 2005, Russia has two options: fight the Chechen Rebels brutally, by the bombing of Chechen villages from the air and invading on the ground; and negotiate with them. The Chechen Rebels have three options: fight the Russian army; engage in direct negotiations that will eventually achieve a *modus vivendi* for both parties; and terrorize civilians inside Russia to demoralize the public. Table 6.2 illustrates the DMs with their options in option form.

Table 6.2: Decision Makers and Options in the Chechnya Conflict

Decision Makers	*Options*	*Status Quo*	
Russia	1. Fight the Chechen rebels	Y	Russia's strategy
	2. Negotiate with Chechen rebels	N	
Chechen Rebels	3. Fight the Russian army	Y	Chechen Rebels' strategy
	3. Negotiate with Moscow	N	
	4. Terrorize inside Russian Federation	Y	

In Table 6.2, the *status quo* state represents an outcome in which Russia fights (as indicated by the Y opposite option 1) and Chechen Rebels fight and terrorize (options 3 and 5), and neither side negotiates (as indicated by the N beside options 2 and 4). Since an option can be taken or not, in this conflict model there are 32 (2^5) mathematically possible states. But some option combinations are infeasible because they require mutually exclusive options (e.g., Russia cannot both fight and negotiate; and Chechen Rebels cannot both negotiate and terrorize) or because of option dependence (e.g., if Chechen Rebels fight or terrorize, Russia will retaliate; and if Russia accepts a de facto independence, the Chechen Rebels will not choose negotiate). Table 6.3 shows the DMs with their feasible states, $S = \{1,2,3,4,5,6,7,8,9,10,11,12\}$; as noted, state 10 is the *status quo* at the time of modeling the conflict.

Table 6.3: Feasible States in the Chechnya Conflict

	States											
Decision Makers	1	2	3	4	5	6	7	8	9	10	11	12
Russia												
1. Fight	N	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y
2. Negotiate	N	N	Y	N	N	Y	N	N	Y	N	N	N
Chechen Rebels												
3. Fight	N	N	N	Y	N	N	Y	N	N	Y	N	Y
4. Negotiate	N	N	N	N	Y	Y	Y	N	N	N	Y	Y
5. Terrorize	N	N	N	N	N	N	N	Y	Y	Y	Y	Y

In this model, preferences over the feasible states were ascertained from the political and historical context of the conflict, and are expressed by a complete preference ordering of the states for each DM. The Russian government does not want to follow the path of the Soviet Union and disintegrate into its constituent parts. Therefore, defeating the Chechen Rebels takes high priority, and succumbing to Chechen Rebels' terror is least preferred, since it might encourage rebellions elsewhere. Russia's preferences are expressed in the state ordering (most to least preferred) <2, 5, 7, 4, 6, 1, 3, 9, 8, 10, 11, 12>. The Chechen Rebels want Russia to withdraw from Chechnya and negotiate an agreement giving them independence from the Russian Federation. Their preference ranking is <6, (1, 3), 9, (7, 11, 12), (4, 8, 10), (2, 5)>, where equally preferred states are enclosed in brackets.

For a later comparison, stability analysis of the standard graph model is shown in Table 6.4. A forward slash in a cell indicates that the state is not assessed for stability under a solution concept listed in the third column. For example, state 4 is stable by default for Russia, and therefore is not assessed for stability under the remaining solution concepts. The analysis reveals that states 7, 11, and 12 are equilibria for all solution concepts, where Russia fights and Chechen Rebels retaliate violently, albeit sometimes they accept negotiation as they implement a terror strategy. States 1, 6, and 9 are GMR, SMR, and SEQ equilibria. States 1 and 2 are peaceful outcomes: either both DMs do nothing or Russia chooses to negotiate. However, state 9 represents an outcome in which Russia negotiates notwithstanding the Chechen Rebels' terror.

Table 6.4: Stability Analysis of the Standard Graph Model of the Chechnya Conflict

		States											
Identical Viewpoints		1	2	3	4	5	6	7	8	9	10	11	12
Russia	Default	NO	NO	NO	YES	NO	NO	YES	NO	NO	YES	YES	YES
	Nash	NO	YES	NO	/	YES	NO	/	NO	YES	/	/	/
	GMR	YES	YES	NO	/	YES	YES	/	NO	YES	/	/	/
	SEQ	YES	YES	NO	/	YES	YES	/	NO	YES	/	/	/
	SMR	YES	YES	NO	/	YES	YES	/	NO	YES	/	/	/
Chechen Rebels	Default	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Nash	/	NO	NO	NO	NO	YES	YES	NO	NO	NO	YES	YES
	GMR	/	NO	YES	NO	NO	YES	YES	NO	YES	NO	YES	YES
	SEQ	/	NO	YES	NO	NO	YES	YES	NO	YES	NO	YES	YES
	SMR	/	NO	YES	NO	NO	YES	YES	NO	YES	NO	YES	YES

6.6.2 The Perceptual Graph Model System for the Chechnya Conflict

For this emotion-laden conflict, the set of feasible states is further reduced, for each DM, by hidden and potential state sets. State 9 implies a weak government that is incapable of protecting its citizens against terror, which is inconceivable for the Russian government. Chechen Rebels will not submit to the Russian armies, and therefore for them states 2 and 5 are hidden. Emotion, therefore, causes Russia and Chechen Rebels to have different emotive mapping functions, which causes inconsistency in the perception of the conflict. As shown in Figure 6.7, Russia's emotive mapping function, ξ_R, maps the feasible set of states into Russia's set of recognized states, $S_R = \{1,2,3,4,5,6,7,8,10,11,12\}$, which is perceived only by

Russia. The Chechen Rebels' emotive mapping function, ξ_{CR}, excludes states 2 and 5, which creates the Rebels' perceived set of recognized states, $S_{CR} = \{1,3,4,6,7,8,9,10,11,12\}$.

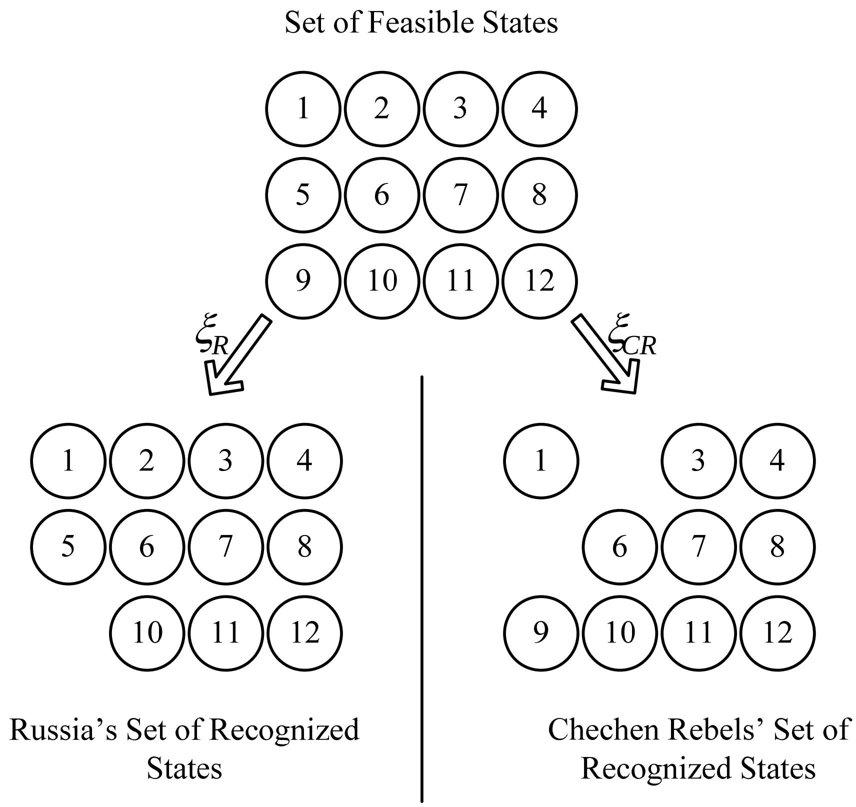


Figure 6.7: DMs' emotive mapping functions of states in the Chechnya conflict.

Accordingly, the set of states privately perceived by Russia but not by Chechen Rebels is $S_R^P = \{2,5\}$, and the set of states privately perceived by Chechen Rebels and not by Russia is $S_{CR}^P = \{9\}$. Consequently, $S^C = \{1,3,4,6,7,8,10,11,12\}$ is the set of commonly recognized states.

Figure 6.8 shows a perceptual graph model system, which consists of a graph model for each DM. Dimmed nodes and arcs indicate inconspicuous states and their associated state transitions. Russia does not know that the Chechen Rebels do not see states 2 and 5, while the Chechen Rebels do not know that Russia is not apprehending state 9.

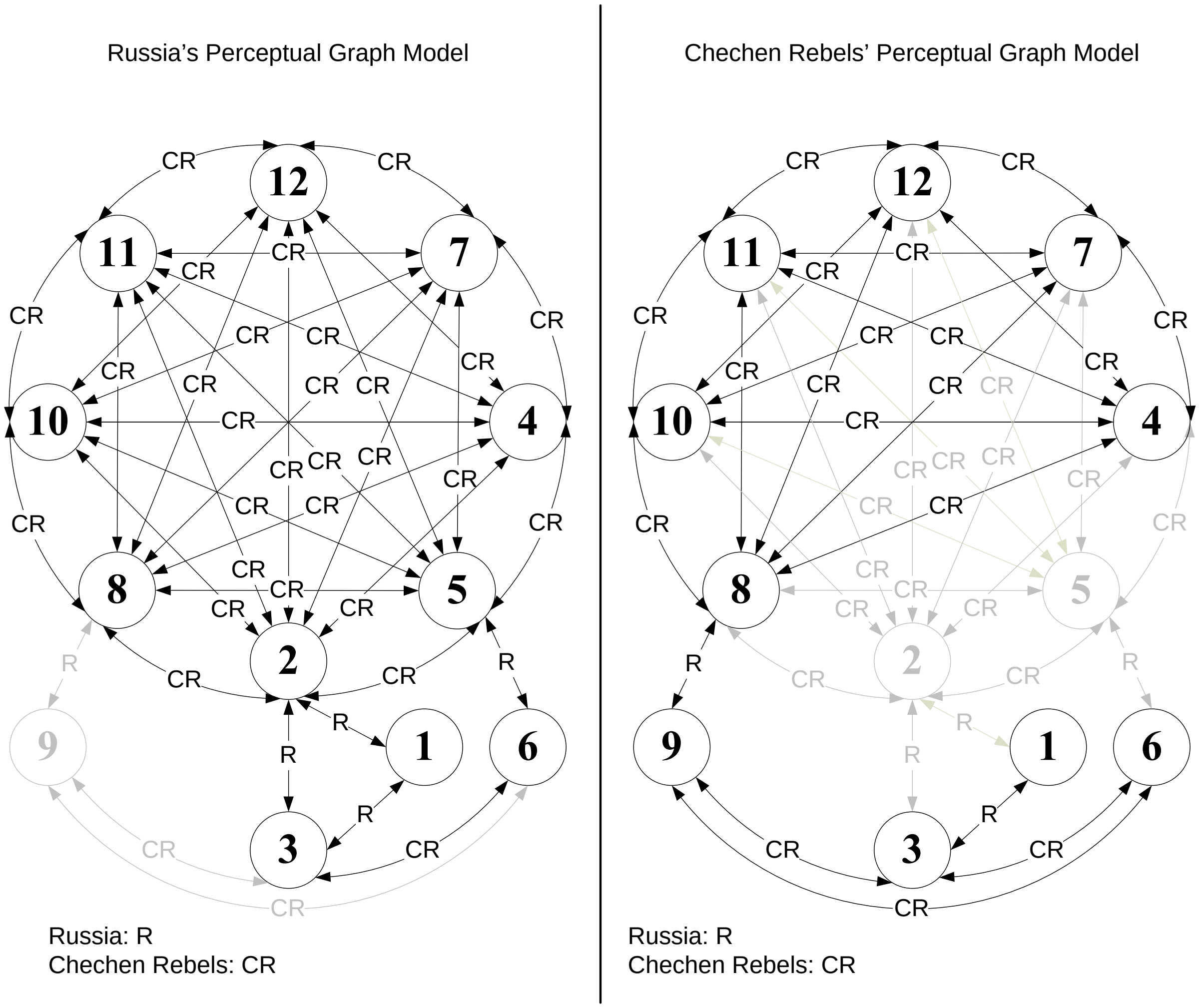


Figure 6.8: A perceptual graph model system for the Chechnya conflict.

Note that the standard graph model serves as a template for building the perceptual graph model system. In particular, DMs' preferences and state transitions in each perceptual graph model are inherited from the standard graph model. Figure 6.9 illustrates the different combinations of viewpoints, and thereby the different perceptual graph model systems, representing the conflict model under different variants of awareness. Russia's viewpoint is $S^C \cap S_R^P$ when $\alpha_R = 1$ and is S_R when $\alpha_R = 0$. On the other hand, Chechen Rebels' viewpoint is $S^C \cap S_{CR}^P$ when $\alpha_{CR} = 1$ and is S_{CR} when $\alpha_{CR} = 0$.

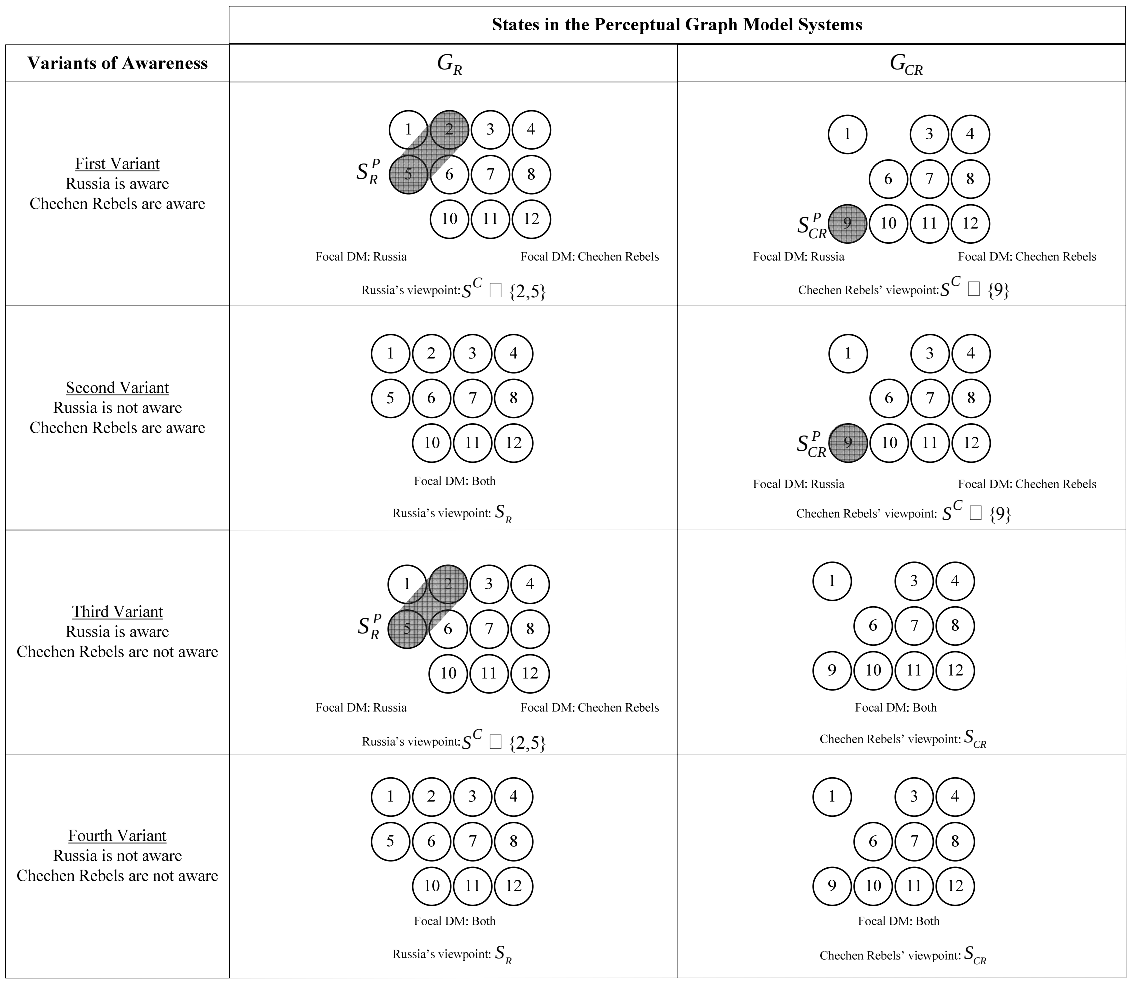


Figure 6.9: Perceptual graph model systems for different variants of awareness.

6.6.3 Perceptual Stability Analysis for the Chechnya Conflict

To analyze the perceptual graph model system of the Chechnya conflict for predicted resolutions, follow the two phases in Figure 6.3. First, apply individual stability analysis twice on every perceptual graph model, using the appropriate form for the solution concepts. Standard solution concepts are used when the owner of a graph is not aware that the opponent has a different graph model. Hence, the stability analysis function of the decision support system GMCR II (Fang, Hipel, and Kilgour, 1993; Fang, Hipel, Kilgour, and Peng, 2003a,b) can be used to examine the stability of states for each DM. The automatic identification of equilibria in GMCR II does not apply, and equilibria must be identified by hand using meta-stability analysis of the perceived graphs. Alternatively, perceptual solution concepts are used when a DM is aware that some states in his or her graph model are not perceived by the opponent. These perceptual solution concepts must be determined by hand. In either case, care must be taken to analyze only states that are recognized by the owner of the graph model for a focal DM.

Stability analyses of Russia's graph model for $\alpha_R = 1$ and $\alpha_R = 0$, respectively, are shown in Tables 6.5 and 6.6, respectively. Note that state 9, columns in grey, is not perceived by Russia. The states that are shown as overall stable for both DMs in Table 6.6 are those reported as equilibria in the standard graph model analysis. However, while states 7, 11, and 12 remain overall stable, Table 6.5 shows dramatic changes from Table 6.4 for the overall stability results. In particular, states 1, 3, and 6 are now perceived by Russia as *GMR and SEQ strategic advantage unstable*, since Russia can take advantage of Chechen Rebels' limited perception of the more preferred states 2 and 5, and not worry about an immediate sanction by Chechen rebels, who do not perceive these UIs. State 3 is also perceived by Russia as *GMR and SEQ strategic disadvantage unstable* for Chechen Rebels, who have the incentive to move unilaterally away from state 3 to state 6 and not realize Russia's sanction, state 5. Moreover, state 9 is no longer perceived by Russia, and states 2 and 5 emerge as private equilibria since they are stable under all solution concepts for Russia, when it is aware that Chechen Rebels do not perceive those states.

Table 6.5: Stability Analysis for Russia's Graph Model, when $\alpha_R = 1$

			States											
				$\in S_R^P$			$\in S_R^P$				$\in S_{CR}^P$			
Russia's Viewpoint			1	2	3	4	5	6	7	8	9	10	11	12
$\alpha_R = 1$	Russia	Default	NO	NO	NO	YES	NO	NO	YES	YES		YES	YES	YES
		ADefualt	/	/	/	/	/	/	/	/		/	/	/
		Nash	NO	YES	NO	/	YES	NO	/	/		/	/	/
		ANash	/	/	/	/	/	/	/	/		/	/	/
		GMR	SAUN	YES	SAUN	/	YES	SAUN	/	/		/	/	/
		SEQ	SAUN	YES	SAUN	/	YES	SAUN	/	/		/	/	/
		SMR	NO	YES	NO	/	YES	NO	/	/		/	/	/
		ASMR	/	/	/	/	/	/	/	/		/	/	/
	Chechen Rebels	Default	YES	/	NO	NO	/	NO	NO	NO		NO	NO	NO
		ADefualt	/	/	NO	NO	/	NO	NO	NO		NO	NO	NO
		Nash	/	/	NO	NO	/	YES	YES	NO		NO	YES	YES
		ANash	/	/	NO	NO	/	NO	NO	NO		NO	NO	NO
		GMR	/	/	SDUN	NO	/	YES	YES	NO		NO	YES	YES
		SEQ	/	/	SDUN	NO	/	YES	YES	NO		NO	YES	YES
		SMR	/	/	NO	NO	/	YES	YES	NO		NO	YES	YES
		ASMR	/	/	NO	NO	/	NO	NO	NO		NO	NO	NO

Table 6.6: Stability Analysis for Russia's Graph Model, when $\alpha_R = 0$

			States											
				$\in S_R^P$			$\in S_R^P$				$\in S_{CR}^P$			
Russia's Viewpoint			1	2	3	4	5	6	7	8	9	10	11	12
$\alpha_R = 0$	Russia	Default	NO	NO	NO	YES	NO	NO	YES	YES		YES	YES	YES
		Nash	NO	YES	NO	/	YES	NO	/	/		/	/	/
		GMR	YES	YES	NO	/	YES	YES	/	/		/	/	/
		SMR	YES	YES	NO	/	YES	YES	/	/		/	/	/
		SEQ	YES	YES	NO	/	YES	YES	/	/		/	/	/
	Chechen Rebels	Default	YES	NO	NO	NO	NO	NO	NO	NO		NO	NO	NO
		Nash	/	NO	NO	NO	NO	YES	YES	NO		NO	YES	YES
		GMR	/	NO	YES	NO	NO	YES	YES	NO		NO	YES	YES
		SMR	/	NO	YES	NO	NO	YES	YES	NO		NO	YES	YES
		SEQ	/	NO	YES	NO	NO	YES	YES	NO		NO	YES	YES

The stability analysis finding for Chechen Rebels' graph model are shown in Tables 6.7 and 6.8 for the indices of awareness $\alpha_{CR} = 1$ and $\alpha_{CR} = 0$, respectively. Note that states 2 and 5, columns in grey, are not perceived by Chechen Rebels. The conclusions in the two tables are rather similar; with the exception of state 8 in Table 6.7, which is perceived by Chechen Rebels as apparently default stable for Russia, states 1, 6, 7, 11, and 12 are perceived to be overall stable under all solution concepts.

Table 6.7: Stability Analysis for Chechen Rebels' Graph Model, when $\alpha_{CR} = 1$

			States											
				$\in S_R^P$			$\in S_R^P$				$\in S_{CR}^P$			
Chechen Rebels' Viewpoint			1	2	3	4	5	6	7	8	9	10	11	12
$\alpha_{CR} = 1$	Russia	Default	NO		NO	YES		YES	YES	NO	/	YES	YES	YES
		ADefualt	NO		NO	/		/	/	YES	/	/	/	/
		Nash	YES		NO	/		/	/	/	/	/	/	/
		ANash	NO		NO	/		/	/	/	/	/	/	/
		GMR	YES		NO	/		/	/	/	/	/	/	/
		SEQ	YES		NO	/		/	/	/	/	/	/	/
		SMR	YES		NO	/		/	/	/	/	/	/	/
		ASMR	NO		NO	/		/	/	/	/	/	/	/
	Chechen Rebels	Default	YES		NO	NO		NO	NO	NO	NO	NO	NO	NO
		ADefualt	/		/	/		/	/	/	/	/	/	/
		Nash	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		ANash	/		/	/		/	/	/	/	/	/	/
		GMR	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		SEQ	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		SMR	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		ASMR	/		/	/		/	/	/	/	/	/	/

Table 6.8: Stability Analysis for Chechen Rebels' Graph Model, when $\alpha_{CR} = 0$

			States											
				$\in S_R^P$			$\in S_R^P$				$\in S_{CR}^P$			
Chechen Rebels' Viewpoint			1	2	2	4	5	6	7	8	9	10	11	12
$\alpha_{CR} = 0$	Russia	Default	NO		NO	YES		YES	YES	NO	NO	YES	YES	YES
		Nash	YES		NO	/		/	/	NO	YES	/	/	/
		GMR	YES		NO	/		/	/	NO	YES	/	/	/
		SMR	YES		NO	/		/	/	NO	YES	/	/	/
		SEQ	YES		NO	/		/	/	NO	YES	/	/	/
	Chechen Rebels	Default	YES		NO	NO		NO	NO	NO	NO	NO	NO	NO
		Nash	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		GMR	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		SMR	/		NO	NO		YES	YES	NO	NO	NO	YES	YES
		SEQ	/		NO	NO		YES	YES	NO	NO	NO	YES	YES

Moreover, a comparison of the stability analysis results in Table 6.6 (Russia's Graph Model with $\alpha_R = 0$) and Table 6.7 or 6.8 shows a consensus in stability conclusions between the unaware Russia and Chechen Rebels. These observations suggest that the resolution of the conflict will be more sensitive to Russia's perception.

The next step is to apply meta-stability analysis to the perceptual graph model system in Figure 6.8, in the order shown in Figure 6.9. Individual stability analyses for both DMs are arranged so that results under the four variants of awareness can be compared. Overall and individual stabilities are consolidated from Tables 6.6 and 6.8, Tables 6,6 and 6,7, Tables 6,5 and 6,8, and Tables 6.5 and 6.7.

The conclusions of the meta-stability analysis are provided in Table 6.9. Grey cells indicate that states are perceived stable by default for one of the DMs. For example, in Nash overall stability, states 1 and 6 are perceived default stable in G_{CR} for Chechen Rebels in all variants of awareness, and states 7, 11, and 12 are perceived default stable in G_R and G_{CR} for Russia in all variants of awareness. A cell labeled as "PE" indicates that the state is privately stable, and therefore a private equilibrium, for the DM who owns the graph model.

For instance, states 2 and 5 are private equilibria in all solution concepts for Russia, which is aware that Chechen Rebels do not perceive the states concerned.

Table 6.9: Meta-Stability Analysis for the Perceptual Graph Model of the Chechnya Conflict

	Nash Overall Stability																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}
Standard													Yes								Yes		Yes	
$\alpha_R = 0 : \alpha_{CR} = 0$		Yes		-						-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 0$		Yes	PE	-					PE	-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 0 : \alpha_{CR} = 1$		Yes		-						-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 1$		Yes	PE	-					PE	-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes

	GMR Overall Stability																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}
Standard	Yes										Yes		Yes				Yes				Yes		Yes	
$\alpha_R = 0 : \alpha_{CR} = 0$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 0$	SAUN	Yes	PE	-	SAUN SDUN				PE	-	SAUN	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 0 : \alpha_{CR} = 1$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 1$	SAUN	Yes	PE	-	SAUN SDUN				PE	-	SAUN	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes

	SMR Overall Stability																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}
Standard	Yes										Yes		Yes				Yes				Yes		Yes	
$\alpha_R = 0 : \alpha_{CR} = 0$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 0$	SAUN	Yes	PE	-					PE	-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 0 : \alpha_{CR} = 1$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 1$	SAUN	Yes	PE	-					PE	-		Yes	Yes	Yes			-				Yes	Yes	Yes	Yes

	SEQ Overall Stability																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}	G_R	G_{CR}
Standard	Yes										Yes		Yes				Yes				Yes		Yes	
$\alpha_R = 0 : \alpha_{CR} = 0$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 0$	SAUN	Yes	PE	-	SAUN SDUN				PE	-	SAUN	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 0 : \alpha_{CR} = 1$	Yes	Yes		-						-	Yes	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes
$\alpha_R = 1 : \alpha_{CR} = 1$	SAUN	Yes	PE	-	SAUN SDUN				PE	-	SAUN	Yes	Yes	Yes			-				Yes	Yes	Yes	Yes

Legend
PE : Private Equilibrium.
SAUN: Strategic Advantage Instability.
SDUN: Strategic Disadvantage Instability.
[shaded box] : States perceived stable by default for a decision maker.

Figure 6.10 summarizes the overall stability found in Table 6.9, as a function of perceptual graphs and variants of awareness. The meta-stability analysis reveals that each of the three states 7, 11, and 12, which is an equilibrium in the standard graph model, is a solid equilibrium under all solution concepts in all perceptual graph models. Thus, if any of these states is attained, it is likely to be a resolution to the conflict. These states represent outcomes in which Russia fights and Chechen Rebels adopt violent strategies.

In addition, states 1 and 6 are transitory equilibria under all solution concepts except the Nash definition. These states are recognized by and overall stable for both Russia and Chechen Rebels in some variants of awareness (when Russia has $\alpha_R = 0$). Although states 1 and 6 represent nonviolent outcomes (either the DMs do nothing or they choose negotiation) and thereby may be considered desirable, their credibility is weak and their sustainability as resolutions to the conflict is precarious.

States 1 and 6 are no longer equilibria (in any sense) as Russia becomes aware that the Chechen Rebels do not perceive states 2 and 5. Under such a circumstance, Russia's awareness of the Chechen Rebels' limited perception makes states 1 and 6 strategic advantage unstable for Russia, although they are overall stable in the Chechen Rebels' graph model.

Furthermore, meta-stability analysis reveals that states 2 and 5 are stable for all solution when $\alpha_R = 1$ from Russia's viewpoint only. States 2 and 5, therefore, become transitory pseudo-equilibria in Russia's graph model under all stability definitions. If these states are attained, Russia will continue fighting and not expect vengeance by the Chechen Rebels. In this case, then, the conclusion that states 2 and 5 are stable may mislead Russian policy towards Chechnya.

The aforementioned analysis, on the one hand, reveals a grim reality for the future of the Chechnya conflict. At the solid equilibria, states 7, 11, and 12, Russia and the Chechen Rebels continue their war of attrition. On the other hand, the existence of the two transitory equilibria, states 1 and 6, shows that if Russia and the Chechen Rebels are able to think two or three moves ahead and behave cautiously, taking into account all of each other's possible moves and countermoves, and if they adopt a unified view of the conflict (a standard graph model), then a peaceful resolution, if achieved, would be stable.

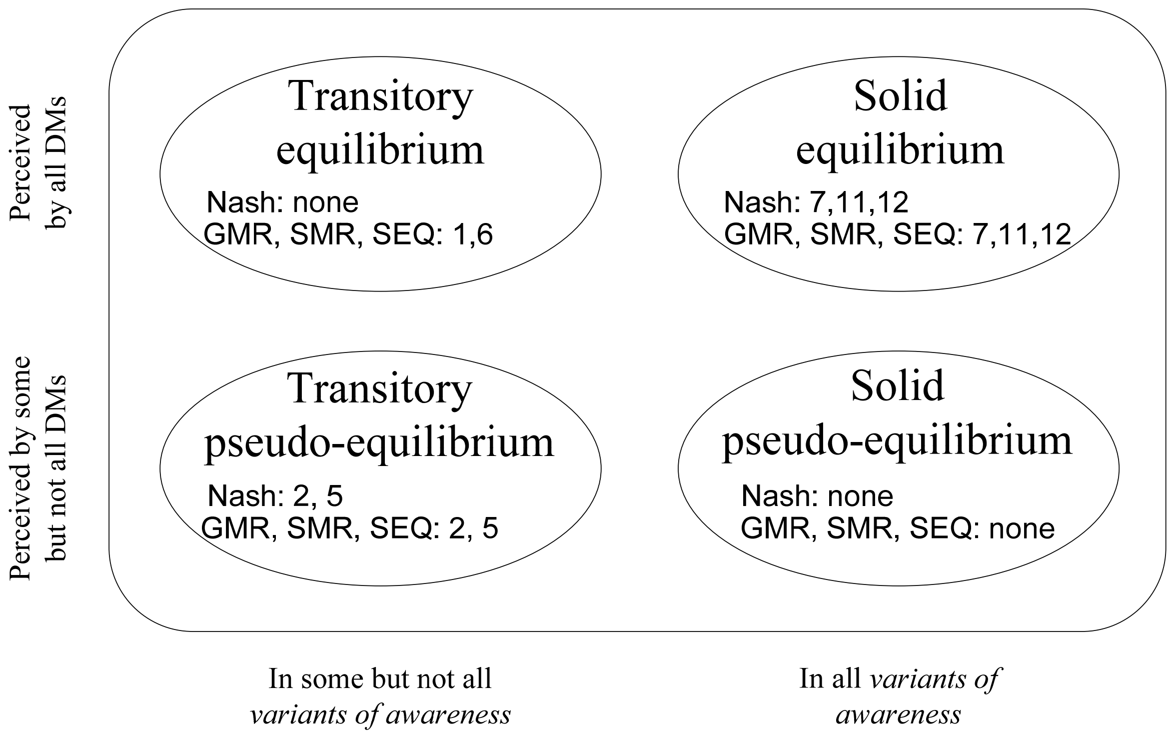


Figure 6.10: A summary of meta-stability analysis of the Chechnya Conflict.

6.7 Inherited Stability Properties

A perceptual graph model system inherits most of its ingredients from a standard graph model. Inherited components include the DMs, states, state transitions and DMs' relative preferences for states. In addition, other standard graph model features are utilized in reformulating standard solution concepts for use in perceptual stability analysis. These are the set of states DM *i* prefers to state *s*, $\Phi_i^+(s)$, the set of states that DM *i* finds equally or less preferred to state *s*, $\Phi_i^{\leq}(s)$, and DM *i*'s reachable list, $R_i(s)$, and unilateral improvement list, $R_i^+(s)$. Hence, every perceptual graph model system consists of sub-models that share many properties with the standard graph model.

Within the standard graph model structure, procedures have been established to assess the stability of states using various solution concepts (stability definitions), which are designed to reflect human behavior under conflict. Sometimes, mapping a standard graph model to a perceptual graph model may affect the stability of a state under standard solution concepts, as illustrated in Figure 6.11. The stability of a state for a focal DM may change because the state is not recognized by the owner of a graph model, or because some state transitions controlled by a DM in the standard graph model become invisible to that DM in the perceptual graph. In the former case, the stability of the state is irrelevant, because it cannot be assessed for stability by the owner of the graph model. But in the latter situation, either the stability status of the state under a particular solution concept is altered (i.e, stable state becomes unstable and unstable state becomes stable), or the state cannot be assessed for stability under the same solution concept because the DM cannot or has no desire to unilaterally move away from it; thereby the stability of the state is limited to perceived default or Nash stability for the focal DM. In Figure 6.11, for instance, a state assessed to be GMR, SEQ, or SMR stable for a focal DM in a standard graph model may be assessed default or Nash stable if all unilateral moves or UIs, respectively, from the state are not perceived by the DM in the perceptual graph model.

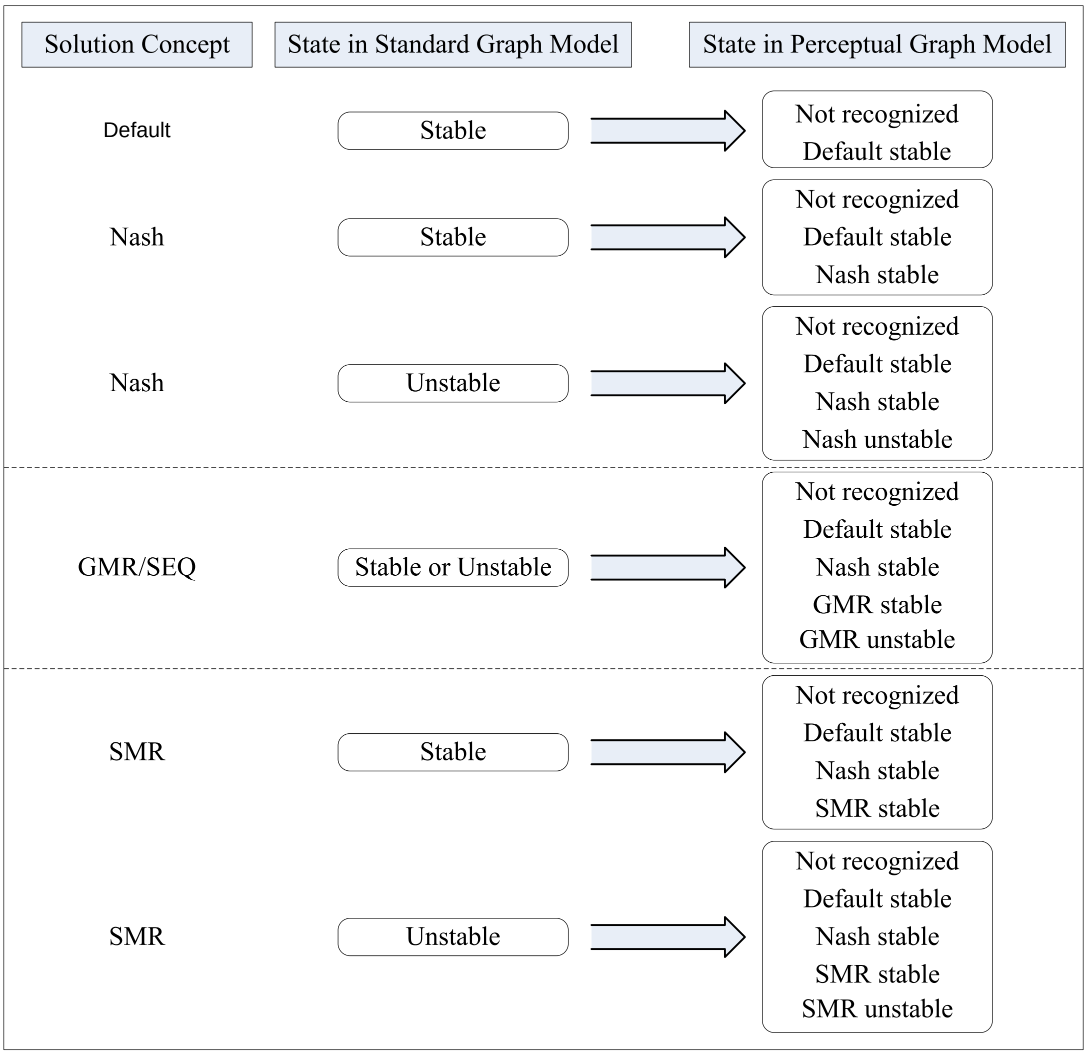


Figure 6.11: Stability properties inherited by perceptual graph model.

Hence, a state that is stable for a DM in the standard graph model may or may not be stable in a perceptual graph model system, from the viewpoint of the DM who perceives it.

Nonetheless, some solution concepts are resilient to DMs' inconsistent perceptions of the conflict; in that their stability properties are preserved as the standard graph model is mapped into sub-models. Understanding these inherited qualities, moreover, may expedite a perceptual stability analysis. Most notably, Nash and SMR stability in a perceptual graph model system can be inferred from a stability analysis of the standard graph model.

The rules embedded in a solution concept identify a current state that a DM may tend to stay at, given that the state is attained. In Nash stability, the basic rule examines whether a focal DM can move unilaterally to a more preferred state. Thus, the absence of unilateral improvements (UIs) indicates that the state is Nash stable. Consequently, the lack of a UI in a standard graph model must be preserved in a perceptual graph model. Hence, if a state is Nash stable for a DM in the standard graph model, the state cannot be unstable in any sub-model for that DM.

Theorem 6.7.1: Persistence of Nash stability

A state $s \in S$ that is Nash stable for a DM in a standard graph model maintains its stability in any perceptual graph model for any DM who perceives it.

Proof (by contradiction):

Suppose that $s \in S_k \cap S_i$ for $i, j \in N$, that $k = i$ or $k = j$, and that the state *s* is Nash stable in *G* for DM *i*. Therefore, $R_i^+(s) = \varnothing$. Assume that the state *s* is *not* Nash stable for DM *i* in a perceptual graph model. Then, either $R_i^+(s) \neq \varnothing$ is true if $\alpha_k = 0$ or $R_i^+(s) \cap S_k \neq \varnothing$ is true if $\alpha_k = 1$. In either case, this contradicts the assumption (in the second case, because $R_i^+(s) \cap S_k \subseteq R_i^+(s)$). Hence, $R_i^+(s) = \varnothing$ must be true if $\alpha_k = 0$ and $R_i^+(s) \cap S_k = \varnothing$ must be true if $\alpha_k = 1$.□

In a 2-DM model, if a state is Nash stable for DM *i* in the standard graph model, then, in DM *k*'s perceptual graph ($k = 1$ or $k = 2$), it will remain Nash stable for DM *i* provided that *k* perceives the state and it is not default or apparently default stable. In the Chechnya conflict, for example, states 2, 5, and 9 are Nash stable for Russia and states 6, 7, 11, and 12 are Nash stable for Chechen Rebels in the standard graph model. The following observations about Nash stability in the sub-models are consistent with Theorem 6.7.1. In G_R, state 9 is not perceived by Russia so it is not assessed for stability for any DM; states 2 and 5 are Nash stable for Russia, and states 6, 7, 11, and 12 are perceived by Russia to be Nash stable for Chechen Rebels. In G_{CR}, states 6, 7, 11, and 12 are perceived to be Nash stable for Chechen Rebels while state 9 is perceived Nash stable for Russia when $\alpha_{CR} = 0$. Notice that when Chechen Rebels are aware of Russia's limited perception ($\alpha_{CR} = 1$) state 9 is not assessed for stability for Russia under any solution concept.

Conversely, a state that is not Nash stable for a DM in standard graph model may or may not be stable in a perceptual graph system from the viewpoint of the DM who perceives it. As an example, state 1 is not Nash stable in the standard graph model for Russia, but it is perceived as Nash stable for Russia in G_{CR} because the Chechen Rebels do not perceive the UI, i.e., state 1. On the other hand, state 8 is not Nash stable for Russia in the standard graph model, but is apparently default stable for Russia when $\alpha_{CR} = 1$ and is not Nash stable for Russia when $\alpha_{CR} = 0$.

In the SMR stability definition, the rules for identifying the stability of a state for a DM extend GMR stability by examining available escapes from sanctions imposed by opponents to all focal DM's UIs. A perceptual graph model system inherits the inescapability property of sanctions from the standard graph model. In other word, the absence of escapes to all opponents' sanctions must be preserved in all sub-models. Hence, a state that is SMR stable in standard graph model cannot be SMR unstable in a perceptual graph model system.

Theorem 6.7.2: Persistence of SMR stability

A state $s \in S$ that is SMR stable for a DM in a standard graph model maintains its stability in any perceptual graph model for every DM who perceives it.

Proof (by contradiction):

Suppose that $s \in S_k$ ¡ S_i for $i, j \in N$, that $k = i$ or $k = j$, and that the state s is Nash stable in G for DM i. Therefore, for every $t \in R_i^+(s)$, $R_j(t) \cap \Phi_i^{\leq}(s) \neq \emptyset$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s)$, $R_i(h) \cap \Phi_i^+(s) = \emptyset$. Assume that the state s is GMR stable but *not* SMR stable for DM i in some perceptual graph model. Then, $R_j(t) \cap \Phi_i^{\leq}(s) \neq \emptyset$, and $\forall t \in R_i^+(s)$, $\forall h \in R_j(t) \cap \Phi_i^{\leq}(s)$, either $\alpha_k = 0$ and $R_i(h) \cap \Phi_i^+(s) \neq \emptyset$ is true or $\alpha_k = 1$ and $R_i(h) \cap \Phi_i^+(s) \cap S_k \neq \emptyset$ is true. In either case, this contradicts the assumption (in the second case, because $R_i(h) \cap \Phi_i^+(s) \cap S_k \subseteq R_i(h) \cap \Phi_i^+(s)$). Hence, $R_i(h) \cap \Phi_i^+(s) = \emptyset$ must be true when $\alpha_k = 0$ and $R_i(h) \cap \Phi_i^+(s) \cap S_k = \emptyset$ must be true when $\alpha_k = 1$. If the state s is not GMR stable in a perceptual graph model, s cannot be assessed for SMR stability in the perceptual graph model.□

In a 2-DM model, if a state is SMR stable for DM *i* in the standard graph model, then, in DM *k*'s perceptual graph ($k = 1$ or $k = 2$), it will remain SMR stable for DM *i* provided that *k* perceives the state and the state is GMR stable for *i*. To paraphrase, the following two conditions must be satisfied to preserve SMR stability: (1) the DM who owns the perceptual graph model must recognize the current state and at least one UI from it, and (2) the UI and any possible sanction must be recognized by all DMs. In the Chechnya conflict, for example, SMR stability in the standard graph model shows that states 1, 2, 5, 6, and 9 are SMR stable for Russia, and states 3, 6, 7, 9, 11, and 12 are SMR stable for Chechen Rebels. In G_R, state 9 is not perceived by Russia so it is not assessed for stability; states 2 and 5 maintain their SMR stability for Russia, while states 1 and 6 maintain their SMR stability except when Russia is aware (i.e., $\alpha_R = 1$) that Chechen Rebels do not perceive states 2 and 5 (states 1 and 6 cannot be assessed for SMR stability because Russia perceives them to be GMR strategic advantage unstable). In G_{CR}, irrespective of Chechen Rebels' awareness, states 6, 7, 11, and 12 are perceived to be SMR stable for Chechen Rebels; states 3 and 9 are not assessed for SMR stability because they are not perceived by Chechen Rebels to be GMR stable.

A state that is SMR unstable for a DM in the standard graph model may or not be stable in perceptual sub-models from the viewpoint of the DM who perceives it. In the Chechnya conflict, for example, state 1 is GMR stable for Russia in the standard graph model, but not always GMR stable in G_R.

On the other hand, an inference can be made about the stability of a state in the standard graph model from its stability in perceptual sub-models. If a state is recognized in all perceptual graph models and stable for a DM for all variants of awareness, then the state must be stable in the standard graph model for that DM.

Theorem 6.7.3

For all $k \in N$, a state $s \in S_k$ that is stable in G_k for DM $i \in N$, under a particular solution concept, must be stable in a standard graph model for DM *i* under that solution concept.

Proof (by contradiction):

A state $s \in S_k$ for $\forall k \in N$, implies that $s \in S^C$. Suppose that the state s is stable in G_k for DM $i \in N$. Then s is perceived by every DM k to be stable for DM *i*. Assume that s is not stable in the standard graph model for DM i. Thus s is not perceived by all DMs to be stable for DM *i*, which contradicts the initial assumption. Hence, state s must be stable in the standard graph model for DM *i*. □

In the Chechnya conflict, states 6, 7, 11, and 12 are stable for the Chechen Rebels, under all solution concepts with the exception of default stability, in all perceptual graph models and all variants of awareness. These states are also stable for the Chechen Rebels in the standard graph model.

Thus, if a state is recognized in all perceptual graph models and the state is unstable for a DM in all variants of awareness, then the state must be unstable in the standard graph model. For instance, in the Chechnya conflict, state 3 is unstable for Russia in (G_R, G_{CR}) for all variants of awareness, and is also unstable for Russia in the standard graph model.

6.8 Consistency of Stability across Perceptual Graphs

A standard graph model represents a view common to all DMs. Because of this commonality, it does not matter who is doing the analysis—any interested observer or DM will apply the same set of rules and reach the same conclusions. Figure 6.12 illustrates the consistency of stability analyses in a 2-DM model. Note that GMR and SEQ are placed in the same zone because, except for the credible sanction condition of SEQ, their definitions are similar. The upper quadrants of the diagram indicate stability analyses for focal DM 1, and the lower quadrants of the diagram indicate stability analyses for focal DM 2. DM 2's stability conclusions for states that are assessed by DM 1 as stable or unstable for the focal DM under a particular solution concept are shown in the right-hand quadrants and left-hand quadrants, respectively.

In a standard graph model, the conclusions DM 1 obtains from assessing the stability of states will be identical to DM 2's conclusions in assessing the same states, as shown in Figure 6.12. For instance, if DM 1 finds a state to be Nash stable for focal DM 2, the state will also be Nash stable for focal DM 2 if it is 2 who carries out the analysis. Thus, a state analyzed by DM 1 as Nash stable for DM 2, represented by a ray that begins at the centre point of Figure 6.12, travels in the lower right-hand quadrant, and passes through the zone of Nash stability for DM 2 (first and second rings), must also pass through the zone of Nash stability for DM 2 in DM 2's analysis (fourth and fifth rings). Similarly, if DM 1 finds a state to be SMR unstable for focal DM 1 (upper, left-hand quadrant of the diagram) DM 2 will reach the same conclusion, i.e., that the state is SMR stable for DM 1.

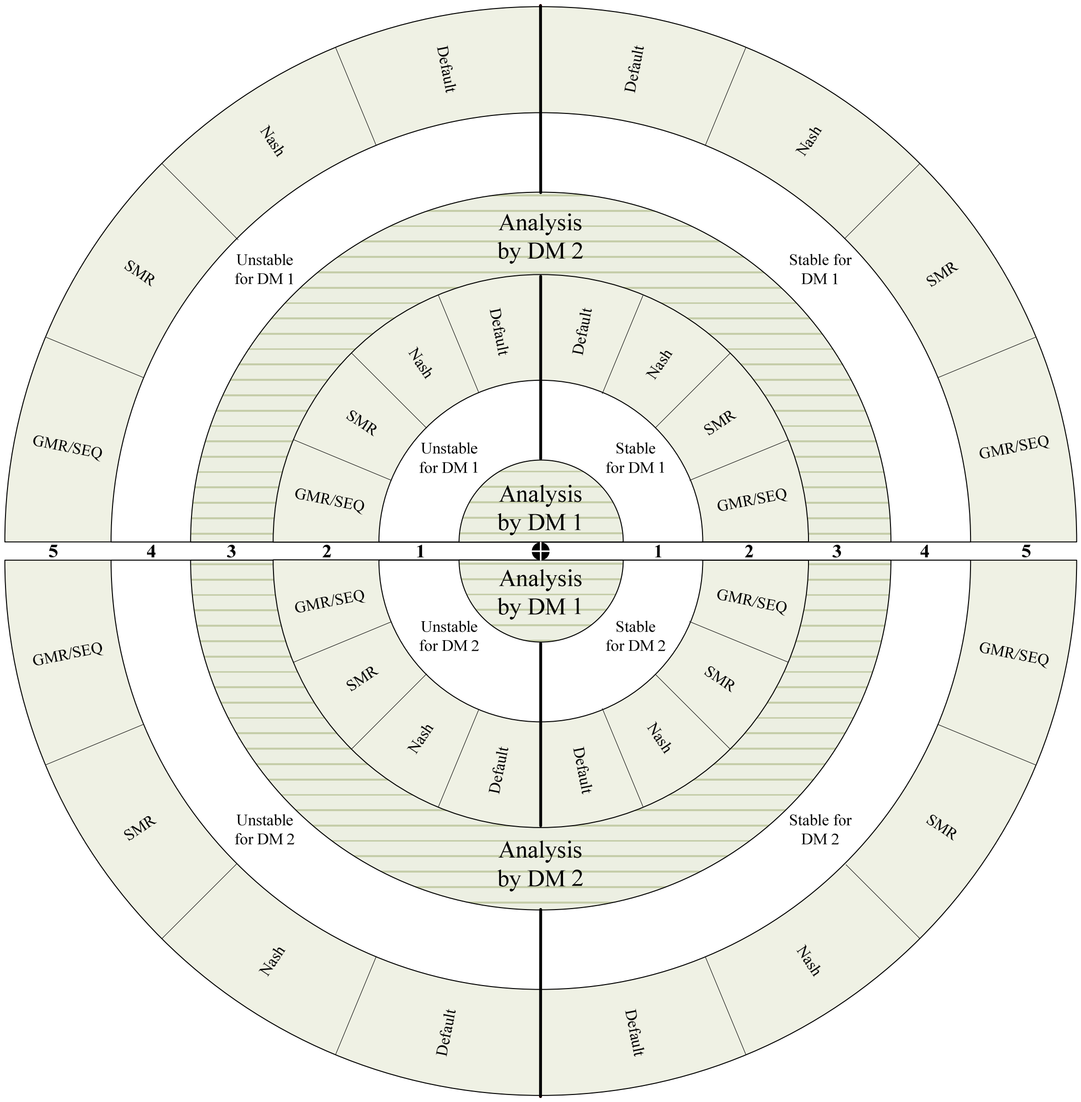


Figure 6.12: Consistency of stability analyses in a standard graph model—the 2-DM case.

This consistency of stability analyses does not apply, in general, in a perceptual graph model system. The outcome of stability analysis of a commonly perceived state in a perceptual graph model for a focal DM may be different in the opponent's perceptual graph model for that focal DM. Figure 6.13 illustrates the inconsistency of stability analyses (of commonly perceived states) in a 2-DM graph model system, in which the DMs are unaware that they are analyzing different graphs, i.e., $(\alpha_1, \alpha_2) = (0,0)$.

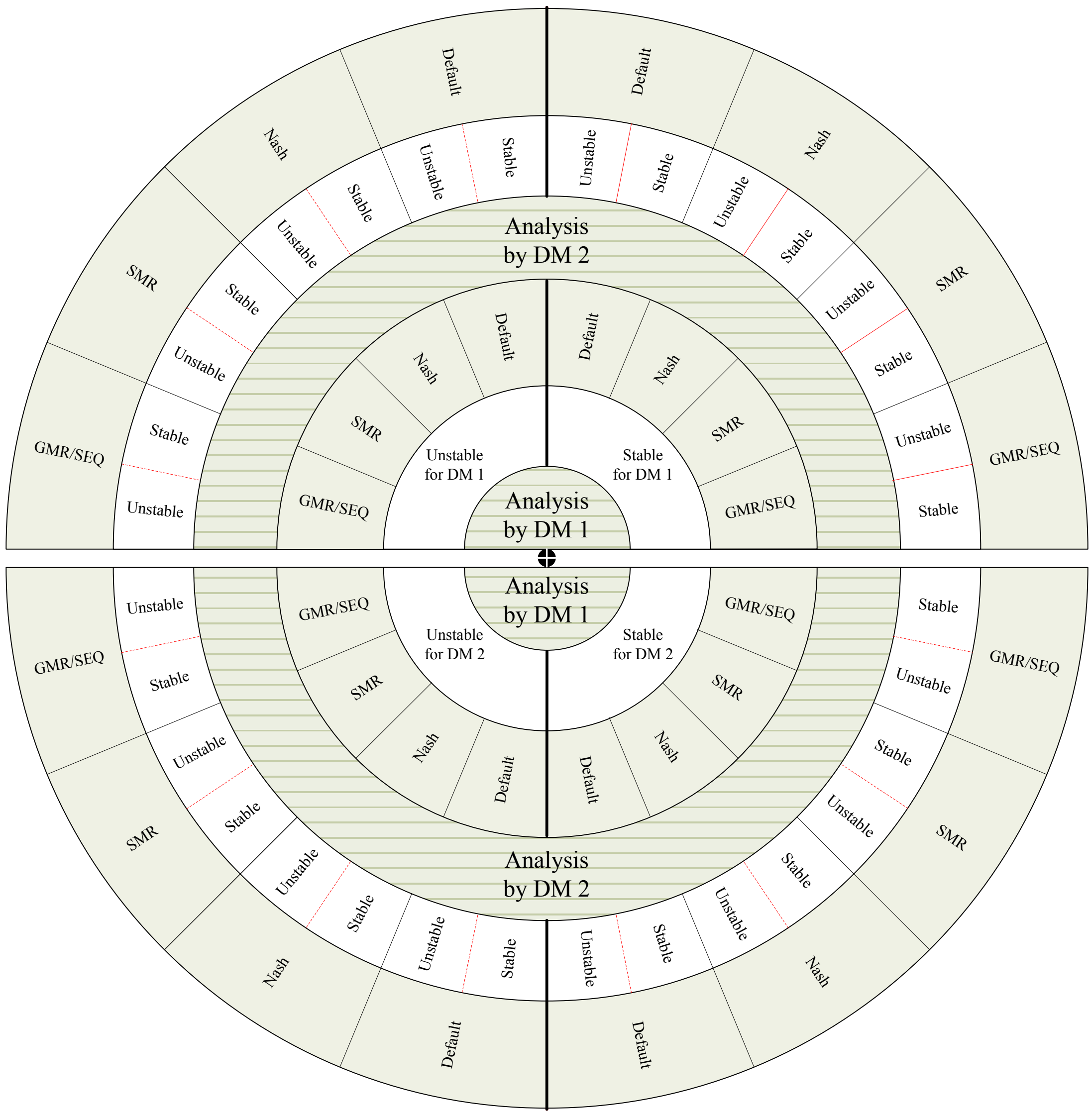


Figure 6.13: Consistency of stability analyses in a 2-DM perceptual graph model system for the case of $\alpha_1 = 0,\ \alpha_2 = 0.$

To interpret Figure 6.13, recall that commonly perceived states are being assessed for stability and compared across DMs' viewpoints. Hence, states in DM 1's perceptual graph model that are recognized by both DMs are being assessed for stability in DM 1's and DM 2's perceptual graph models, respectively. The difference between Figures 6.12 and 6.13 is that in the latter a state that is assessed by one DM to be stable (or unstable) in a graph model for a focal DM may be assessed by the DM's opponent as unstable (or stable) for that focal DM. In general, inconsistencies in the sets of states perceived by the DMs may affect stability under a particular solution concept. Thus, a state in G_1 that is assessed to be stable by DM 1 (upper right-hand quadrant) may change its stability status in G_2. For instance, if focal DM 2 has a UI from state s, and that UI cannot be sanctioned by the opponent 1, then state s is GMR unstable in G_1. But, when the same state is being assessed for GMR stability in G_2 for focal DM 2, state s is GMR stable if there is a possible sanction by 1 in 2's privately perceived set of states, S_2^P. Thus, a ray that begins at the centre point of Figure 6.13, travels in the lower left-hand quadrant, and passes through the zone of GMR instability for DM 2 (first and second rings) may pass through the zone of GMR stability for DM 2 in DM 2's analysis (fourth and fifth rings). Accordingly, a state that is perceived GMR unstable in G_1 for the focal DM 2 may be either stable or unstable in G_2.

The consistency of stability analysis conclusions improves if at least one DM knows that the DMs are analyzing different graph models. In other words, if a DM becomes aware of the states in his or her graph model that are not perceived by the opponent, then under certain conditions stability analyses of commonly perceived states become more consistent across all perceptual graph models. Figures 6.14 and 6.15 illustrate the consistency of stability analyses in a 2-DM model for DMs 1 and 2, respectively. Notice that DM 1 is assumed to be aware that DM 2 is analyzing a different graph but DM 2 lacks this knowledge about DM 1, i.e., $(\alpha_1, \alpha_2) = (1, 0)$.

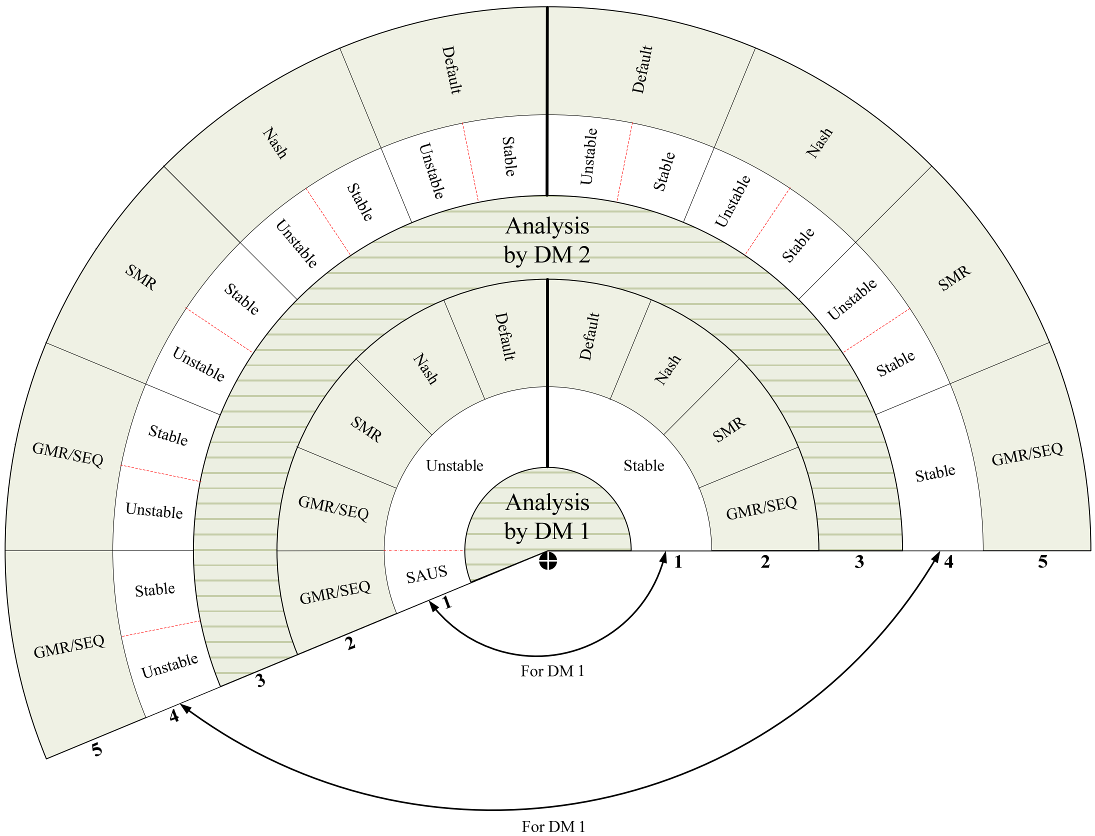


Figure 6.14: Consistency of stability analyses for focal DM 1 in a 2-DM perceptual graph model system in the case of $\alpha_1 = 1, \alpha_2 = 0$.

SAUS: strategic advantage unstable.

Recall that a commonly perceived state in G_1 is assessed by DM 1 to be default, Nash, or SMR stable for a focal DM iff there is, respectively, no unilateral move (UM) to and from the state, no UI from the state, or no escape from the opponent's sanctions, in S_1. DM 2's stability assessment of the same state in G_2 for any of these solution concepts depends on whether a UM, a UI, or an escape, respectively, is present in S_2^P. Hence, a state that is perceived by DM 1 to be stable by default, Nash, or SMR for either DM may or may not be perceived as stable by DM 2, as shown in right-hand quadrants of Figures 6.14 and 6.15. Notice that for a state to be SMR, both UIs and sanctions must be commonly recognized.

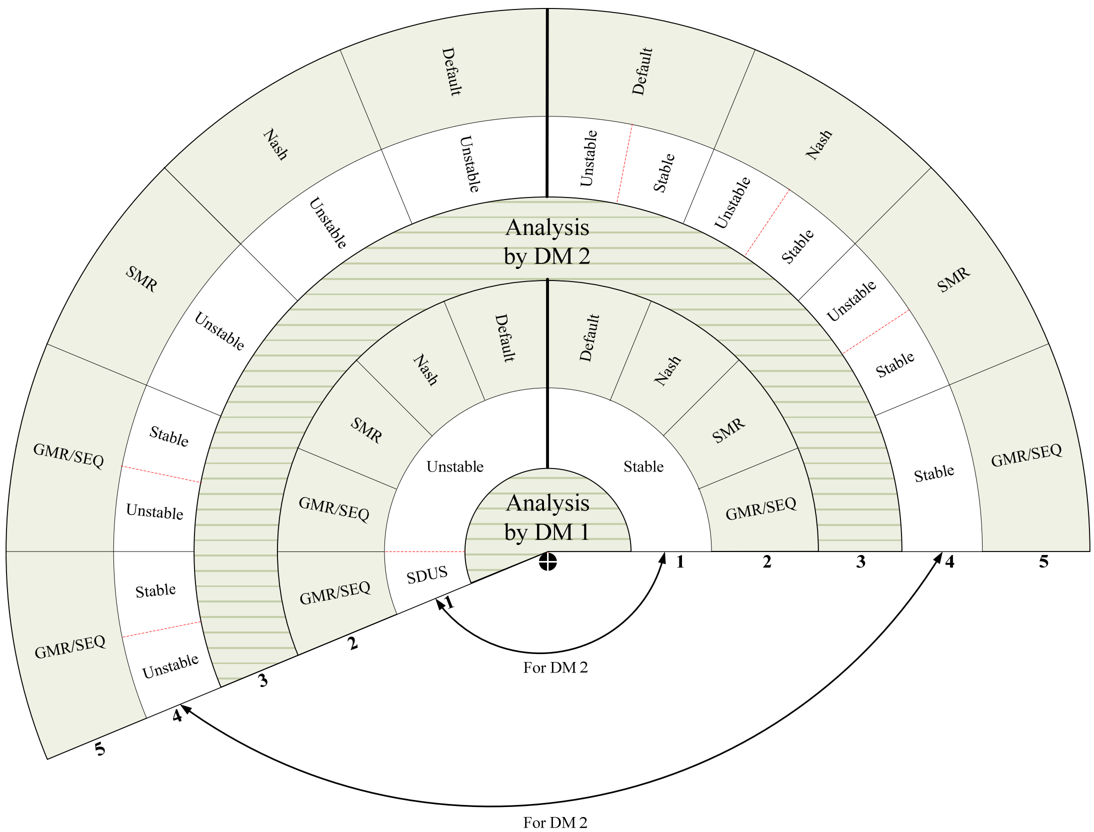


Figure 6.15: Consistency of stability analyses for focal DM 2 in a 2-DM perceptual graph model system in the case of $\alpha_1 = 1, \alpha_2 = 0$.

SAUS: strategic advantage unstable. SDUS: strategic disadvantage stable.

On the other hand, a DM who is more aware has an advantage over his or her opponent. A commonly perceived state in G_1 is perceived by DM 1 to be default, Nash, or SMR unstable for DM 2 iff there exists a UM, a UI, or an escape to DM 1's sanction, respectively, in S^C. If DM 2 analyzes the same state according to these solution concepts he or she will reach the same conclusions, as shown in the upper left-hand quadrant of Figure 6.15. Hence, identifying default, Nash and SMR unstable states for DM 2 may provide DM 1 with more insights about DM 2's perception. As such, DM 1 may be able make inferences about which states are perceived by DM 2 or about which states DM 2 finds stable under these solution concepts.

Furthermore, a state in G_1 is assessed by DM 1 to be GMR stable for either DM iff both the UIs and any possible sanction are commonly perceived by the DMs. By virtue of its rules, therefore, GMR stability must be consistent across the graph models (right-hand quadrants of Figures 6.14 and 6.15). But as illustrated in the lower left-hand sectors of Figures 6.14 and 6.15, DM 1's awareness of DM 2's lack of perception of some states may cause a GMR unstable state to be GMR strategic advantage unstable (SAUS) for focal DM 1 (as in Figure 6.14) or GMR strategic disadvantage unstable (SDUS) for focal DM 2 (as in Figure 6.15). In both cases, DM 2 may or may not find the state stable.

Greater consistency of stability conclusions of DM 1 and DM 2 is achieved when both DMs are aware that they are analyzing different graph models, i.e., $(\alpha_1, \alpha_2) = (1,1)$. Figures 6.16 and 6.17 illustrate the consistency of stability analyses for focal DMs 1 and 2, respectively. Commonly perceived states that are assessed by DM 1 to be stable for 1 under a particular solution concept are also assessed by DM 2 in G_2 to be stable for 1, as shown in the right-hand quadrant of Figure 6.16. For instance, a state s is perceived by DM 1 to be SMR stable iff DM 1 has no escape in S_1 to DM 2's sanction. In G_2, DM 2's assessment of SMR stability of state s depends upon whether there is an escape for DM 1 in S_2^P. Thus, DM

2 perceives state *s* to be SMR stable for DM 1 if no escape exists in S_2, and apparently SMR stable if all escapes are in S_2^P.

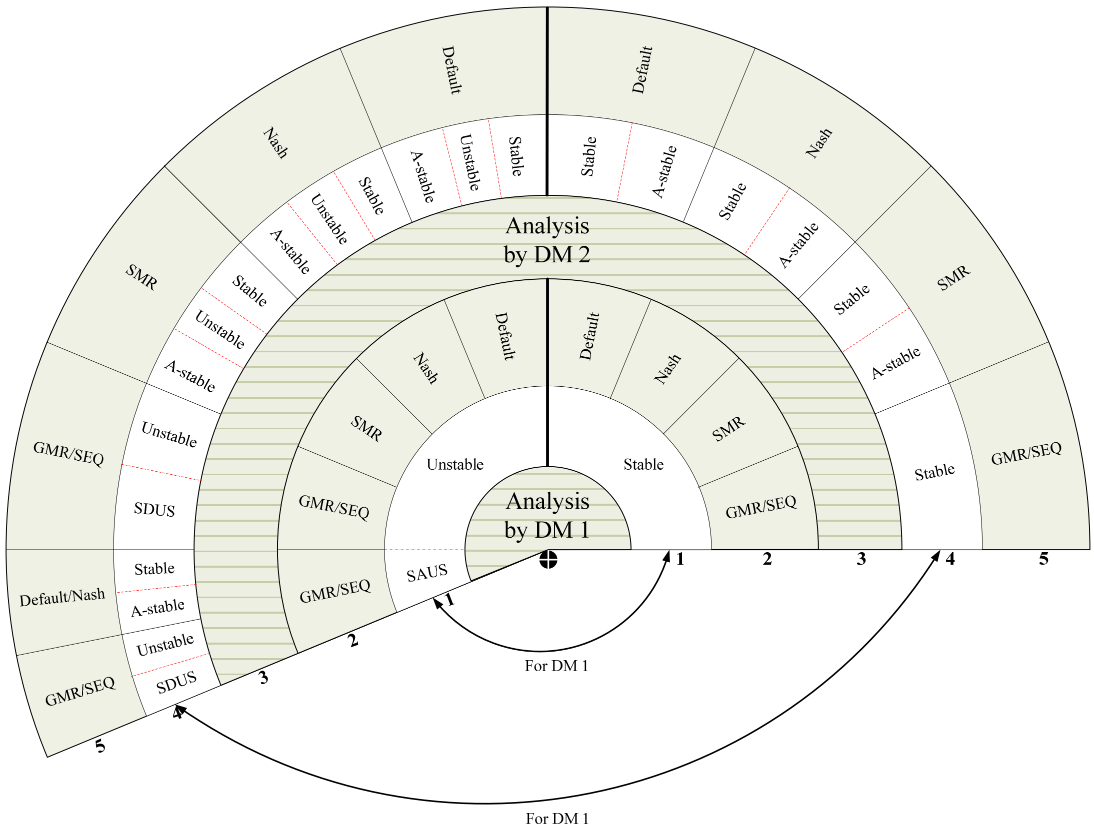


Figure 6.16: Consistency of stability analyses for focal DM 1 in a 2-DM perceptual graph model system in the case of $\alpha_1 = 1, \alpha_2 = 1$.

SAUS: strategic advantage unstable. SDUS: strategic disadvantage stable. A-stable: apparently stable.

As indicated in the upper left-hand quadrants of Figure 6.16 and 6.17, DMs 1 and 2 come to compatible conclusions regarding a state perceived by any DM to be GMR unstable for DM 1, because the absence of a sanction in S^C is recognized by both DMs. For instance, consider a state *s* assessed by DM 1 to be GMR unstable for 1. In G_2, if DM 2 has a sanction for DM

1's possible UI in S_2^P, then the state *s* is perceived by 2 to be GMR strategic disadvantage unstable for DM 1, as shown in the GMR/SEQ zone in the upper left-hand quadrant of Figure 6.16. Hence, a state that is GMR unstable for DM 1 will also be perceived by DM 2 to be unstable for DM 1, albeit for different reasons. Similarly, consider a state *s* assessed by DM 1 to be GMR unstable for DM 2, as shown in the GMR/SEQ zone in the upper left-hand quadrant of Figure 6.17. If DM 2 carries out the GMR stability analysis for focal DM 2, he or she will find that state *s* is either GMR unstable or GMR strategic advantage unstable, depending on whether there is a possible sanction by DM 1 in S_2^P.

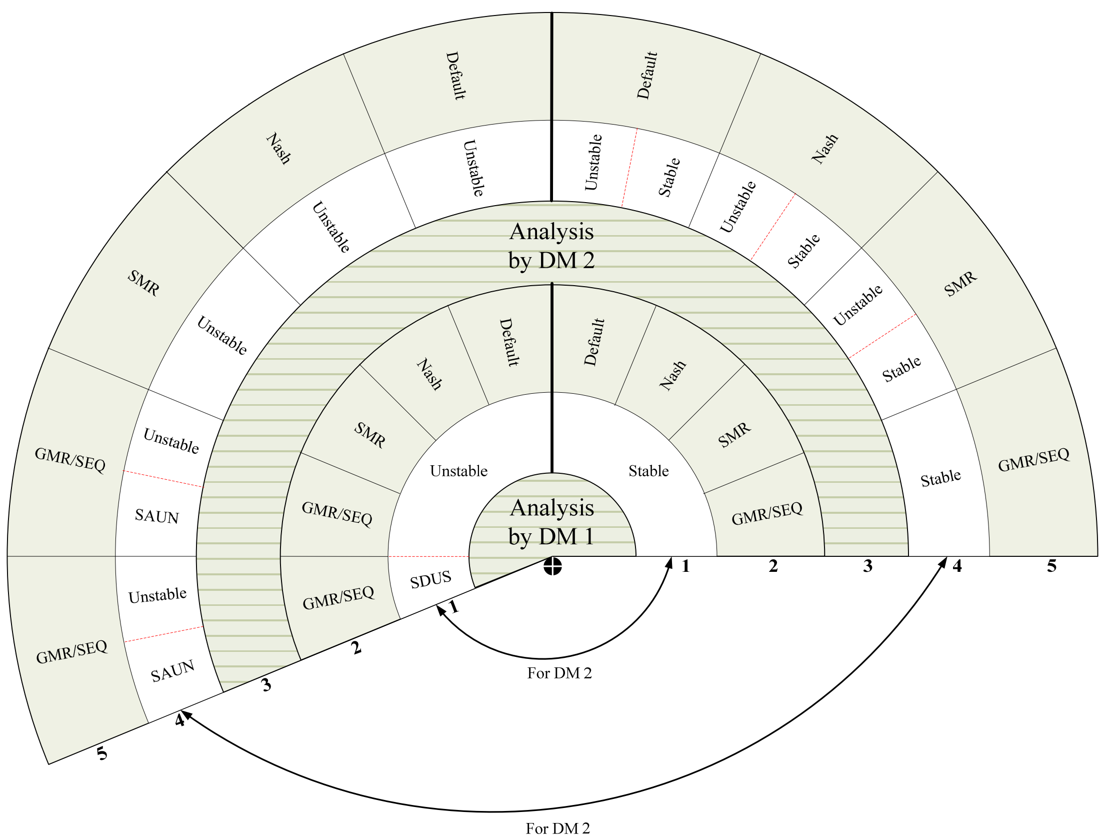


Figure 6.17: Consistency of stability analyses for focal DM 2 in a 2-DM perceptual graph model system in the case of $\alpha_1 = 1, \alpha_2 = 1$.

Furthermore, a state is perceived by DM 1 to be GMR strategic advantage unstable iff DM 1 has a UI in S_1^P, or the UI is commonly perceived by both DMs and every possible sanction by DM 2 belongs to S_1^P. Therefore, DM 2 may assess the state to be stable by default for DM 1 if there exists no UM in S_2, or apparently stable by default if all UMs are in S_2^P. Similarly, DM 2 may assess the state to be Nash stable for DM 1 if there exists no UI in S_2, or apparently Nash stable if all UIs are in S_2^P as shown in the GMR/SEQ zone in the lower left-hand quadrant of Figure 6.16.

The DMs have similar views about GMR instability of a state for focal DM 2, but they may not agree about who is taking advantage of the instability. The lower left-hand quadrant of Figure 6.17 shows that a state that is assessed by DM 1 to be GMR strategic disadvantage unstable is assessed by DM 2 to be GMR unstable for 2 if there is no possible sanction in S_2 by DM 1 against 2's UI. However, DM 2 may also perceive the state s to be GMR strategic disadvantage unstable if all of DM 1's possible sanctions are in S_2^P. In the former case, only DM 1 may take advantage of the instability of the state; in the latter case, both DMs may take advantage of the instability.

6.9 Summary

This chapter is devoted to procedures within the paradigm of the Graph Model for Conflict Resolution that account for inconsistencies in the perception of conflict, as a consequence of, for example, emotion in state identification. Perceptual graph models and a graph model system are defined. Then, perceptual stability analysis is developed as a two-phase approach to assess the stability of states in all perceptual graph models and for all variants of awareness. For the 2-DM case, perceived default stability was defined, and the standard solution concepts of Nash, GMR, SEQ, and SMR were extended to situations in which the owner of a perceptual graph model is aware that other DMs do not recognize some states in his or her graph model. New categories of equilibria are also proposed, including definitions that gauge the robustness and sustainability of a equilibrium. Furthermore, the inherited stability properties of Nash and SMR solution concepts and the consistency of different stabilities across perceptual graphs are discussed for the 2-DM case. Finally, the Chechnya conflict is used as illustrative case of the theoretical developments in this chapter.

Chapter 7

Conclusions and Future Research

Strategic conflict is an inevitable phenomenon that characterizes the relational dynamics of individuals who perceive the attainability of their own goals to be undermined by the individual goal-seeking capabilities of others (Obeidi, Hipel, and Kilgour, 2005). Specifically, conflict is a process that commences with the establishment of an issue, and then evolves through stages involving both emotions and strategic choices. The Graph Model for Conflict Resolution constitutes a flexible, yet parsimonious, paradigm for modeling and analyzing strategic conflict (Kilgour, Hipel, Fang, and Peng, 2001; Fang, Hipel, and Kilgour, 1993). A graph model captures all relevant components normally present in a strategic conflict: two or more independent, interacting DMs, courses of action that determine outcomes, and relative preferences over the possible outcomes.

7.1 Summary of Contributions

The centrality of emotion in conflict and the need for research on the incorporation of emotions into conflict analysis and resolution techniques cannot be emphasized enough. The main objective of this research is to advance mathematical structures and definitions that accurately and rigorously include perceptions and emotions within the paradigm of the Graph Model for Conflict Resolution. Figure 7.1 shows how the major contributions of this thesis are embedded within the Graph Model structure.

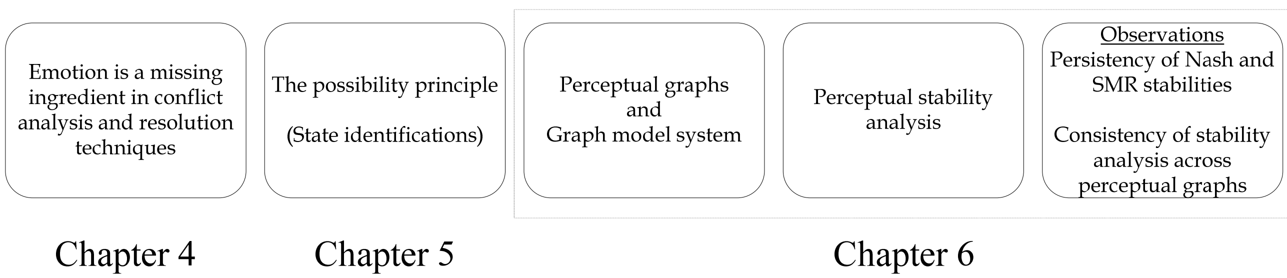


Figure 7.1: Major research contributions of the thesis.

The main objective of Chapter 4 is to demonstrate that emotion is unquestionably an essential ingredient in conflict. Taking a multidisciplinary approach, it was shown that the isomorphism between the characteristics that define and drive conflict and those that engender emotions makes it appropriate to reconcile emotions with current conflict analysis techniques. This is because a conflict permeated with dissimilar values, beliefs, and cultures is more likely to engender negative emotions among stakeholders, and therefore emotions should be part of the conflict model.

State identification is a crucial step in determining outcomes (states) to be considered in the modeling of a conflict. The proposed *possibility principle* advocates that emotion plays an important role in determining how DMs conceptualize a conflict: by envisaging future outcomes and shaping conflict behavior. Attention is focused on two subsets of the conventional set of feasible states: the *hidden* states and the *potential* states. The hidden states are those states that may be invisible to a controlling DM because he or she has strong negative emotion, such as fear or anger; and the potential states are those states that may be invisible to a controlling DM because he or she lacks positive emotion, such as love and joy, which promotes a sense of trust and rapport among DMs. The possibility principle advances the modeling algorithm (Figures 2.2 and 6.1) by operationalizing the consequences of emotion on the actions that are perceived to be available and the actual choices that are made. Therefore, an accurate representation of conflict necessitates eliminating some logically valid states from the model to reflect the conflict as perceived by a DM.

Embedding the possibility principle within the Graph Model framework may modify a DM's directed graph by restricting the set of feasible states according to the DM's emotion. Consequently, this modification in the set of feasible states may indirectly alter state transitions and pairwise comparisons of states that belong to all DMs. Hence, applying the possibility principle requires a new system for modeling and analysis, allowing for each DM to view the conflict independently and privately.

Chapter 6 provides a second advance in the Graph Model methodology, including the development of the perceptual graph models and an associated graph model system. A perceptual graph model is an integrated graph model that reflects a DM's perception and awareness of other DMs' perceptions. As such, a perceptual graph model inherits its basic ingredients from a standard graph model, but with some modifications. Thus, a DM's perceptual graph model is based upon the set of states recognized by the DM; the state transitions that are wholly contained within these recognized states; and the DM's perception of all DMs' relative preferences among states. In addition, a perceptual graph model must reflect the DM's knowledge of whether other DMs recognize all states in his or her model. Hence, an *index of awareness* that describes such knowledge is used to define the DM's *viewpoint*, which guides his or her strategic behavior. Subsequently, a graph model system compiles all DMs' perceptual graph models, and expresses the perspective used by every DM in viewing and analyzing the conflict. A combination of all DMs' perspectives defines a *variant of awareness* for the graph model system. Therefore, for each variant of awareness a perceptual graph system must be defined.

When there are discrepancies in the perception of conflict, the conventional stability analysis becomes ineffective in the assessment of resolutions. Chapter 6 includes another major contribution of this research, the development of perceptual stability analysis, as depicted in Figure 6.3. The underlying structure of perceptual stability analysis is an expansion of standard stability analysis into a two-phase approach. In Phase 1, each perceptual graph model is analyzed from the point of view of its owner by assessing the stability of perceived states for each DM in the model and using the appropriate solution concept. If the owner of a graph model is aware of the presence of other perceptions for the conflict, perceptual solution concepts are used to analyze the stability of states he or she perceives; whereas, if the owner of a graph model believes that there is only a single graph model for the conflict, only standard solution concepts are employed in the analysis. The newly developed perceptual solution concepts are extensions of the standard solution concepts Nash, GMR, SEQ, and SMR, which are applicable to the 2-DM case. Two important observations have been made: 1) a focal DM's lack of perception may cause some states to be apparently stable (Nash or SMR) for the DM, whereas in the standard graph model these states are unstable; 2) a DM's lack of perception may generate a class of GMR and SEQ strategic instabilities.

The conclusions obtained in Phase 1 are not sufficient to predict resolutions. In Phase 2 of perceptual stability analysis, meta-stability is employed on the Phase 1 findings. This meta-stability analysis consolidates private and overall stabilities across all perceptual graph models to identify states that are equilibria, or states perceived to be overall stable in all graph models, and pseudo-equilibria, which are states perceived to be overall stable in some but not all graph models. Then, the equilibria and pseudo-equilibria thus obtained are consolidated across all variants of awareness to gauge the robustness and sustainability of the analysis. States that are equilibria in all variants of awareness are solid equilibria; states that are equilibria in some but not all variants of awareness are transitory equilibria. Likewise, similar conclusions are drawn for states that are pseudo-equilibria.

The observations about the resilience of Nash and SMR stabilities with respect to inconsistent perceptions and the consistency of stability analyses across perceptual graph model for the 2-DM case, represent a major contribution of this research. In addition, the illustrative examples of the real-life disputes in Chapter 5, the US-North Korea conflict, and Chapter 6, the Chechnya conflict, demonstrate how these new developments can be applied in practice.

7.2 Future Research

Although the theoretical contributions outlined in Figure 7.1 advance the Graph Model for Conflict Resolution into a new territory in which emotion, perception and strategy are reconciled, there are further critical issues to be considered. Some promising research opportunities are as follows:

- The general principle of the two-phase approach to perceptual stability analysis is not dependent on the structure of the decision problem. In other words, it can be applied to any conflict, whether the DMs' perceptions are consistent or inconsistent. Thus, developing further case studies to guide and motivate research is crucial.
- The perceptual solution concepts of general metarationality, symmetric metarationality, and sequential stability in Section 6.4 and the constructions of the index of awareness and viewpoint in Section 6.5.1 are exclusive to the 2-DM case. Hence, further extension of these perceptual solution concepts to the *n*-DM case, taking into consideration all possible sequence of opponents' moves, will make perceptual stability analysis more widely applicable. As for the DMs' index of awareness and viewpoints, the *n*-DM case requires some critical changes that recognize whether a DM is aware of some but not all other DMs' perceptions. For example, a vector of awareness $\boldsymbol{\alpha}_i^k = [\alpha_1^k, \alpha_2^k, ..., \alpha_n^k]$ could represent whether DM k is aware or unaware of DM i's lack of perception of some states in G_k. A change in the index of awareness will subsequently alter the viewpoint construct. It is believed that future refinements of these two important concepts will lead to a rigorous

perceptual stability analysis that is applicable to conflict with complex levels of perception.

- Figure 6.1 describes the direct effect of applying the possibility principle to the conventional set of feasible states. Only those states recognized by a DM are used in the DM's perceptual graph model. It is also implied that DMs' state transitions in the perceptual graph models are inherited from the standard graph model. However, state transitions may change in response to modifications of the set of feasible states. In other words, changes in state transitions could be indirect. Nonetheless, as depicted in Figure 6.2, it is reasonable to assume that the possibility principle may directly apply to the perception of state transitions, and not just alter them by proxy. In the Graph Model, for instance, it is usually assumed that DMs recognize all available unilateral movements and improvements, but this assumption may not always be valid. If the means for reaching a state is not apprehended, a DM will not consider moving to it. To illustrate, consider hostilities between two parties in which both DMs agree that it is important to find a resolution because they both have the right to live peacefully and independently. However, even though they could envisage a final and just resolution, the DMs may not be able to recognize the means for achieving that resolution. Their emotions may block them from seeing certain moves. It will be interesting to investigate the direct role of emotions on perceiving state transitions.
- In Sections 5.3.2 and 6.1, it is assumed that, when the possibility principle is applied, the DMs' relative preference relations among states are preserved. This assumption satisfies the property of independence of irrelevant alternatives (Arrow, 1963). To illustrate, suppose a DM expresses his or her preference over the three states x, y,

and z. If the DM prefers x to y, y to z, and x to z, then the DM's preference structure can be expressed by ordering the states in the form of $x \succ y \succ z$. Suppose that the state z is irrelevant, and thereby is eliminated. According to Arrow's property, the DM's preference structure will remain the same, although the pairwise comparisons of states will change as only $x \succ y$ matters. However, as a referee for an article published by Obeidi, Hipel, and Kilgour (2005) commented: "In addition to modifying the graph model, it is plausible that the preference structure may also change with emotions beyond dropping preferences associated with non-visible states." Thus, it appears that the possible effects of emotion in changing DMs' preference structures may be a fertile venue for future research.

- To permit a conflict analysis and resolution technique to be expeditiously used by practitioners and researchers, it should be implemented in a decision support system, (Hipel and Obeidi, 2005). The decision support system GMCR II (Hipel, Kilgour, Fang, and Peng, 1997; Fang, Hipel, Kilgour, and Peng, 2003a,b) allows the methodology of the Graph Model for Conflict Resolution to be applied easily to real-world disputes. However, the advances presented in this research, particularly perceptual stability analysis, are yet to be implemented in a decision support system. Hand calculations are used in all illustrative examples presented so far, and they can be lengthy and tedious. In order to make the new developments accessible to users, they should be integrated into an updated version of GMCR II. Therefore, another promising future research topic is to operationalize in software the theoretical principles presented in Chapters 5 and 6 of this thesis.

- To support the validity of the theoretical advances presented in Chapters 5 and 6, carefully designed empirical experiments or a computer simulations of the procedures are recommended. Experimental tests of interactive decision situations either with students or with other subjects can provide evidence of the applicability of the possibility principle and perceptual stability analysis in conflict. Computer-simulated tests can also help in understanding how DMs perceive outcomes and what resolutions they may contemplate.

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