

Option Effectiveness in the Graph Model for Conflict Resolution

by

Taha Alhindi

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Applied Science
in
Systems Design Engineering

Waterloo, Ontario, Canada, 2018

©Taha Alhindi 2018

AUTHOR'S DECLARATION

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

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

Abstract

The Graph Model for Conflict Resolution (GMCR) is expanded by designing a novel approach for the evaluation of the effectiveness of actions or options controlled by the decision makers (DMs) in a dispute with respect to the potential resolutions or equilibria. This new procedure, called Option Effectiveness, determines the relative importance of each option based on its selection within each resolution contained in the set of equilibria, as well as the types of solution concepts, or behavior under conflict, that form the equilibria. The solution concepts, or stability definitions, used in this method consist of Nash, Sequential Stability (SEQ), Symmetric Metarationality (SMR), and General Metarationality (GMR). More specifically, the strength of an equilibrium type from strongest to weakest is Nash, SEQ, SMR, and GMR. Based on this, the effectiveness or impact of a given option is calculated according to its presence in an equilibrium. This permits the options to be ranked according to their importance or effectiveness in resolving the dispute under consideration. By better understanding which options are crucial, a given DM can focus his effort on choosing strategies which will have a bigger impact on what occurs as the conflict evolves over time to a final resolution.

The Option Effectiveness approach was tested and refined by applying it to four different real-world conflicts. In particular, the ongoing trade dispute between the United States (US) and China over a number of different trade agreements and financial institutions is modeled and analyzed at three points in time using the GMCR methodology in combination with the

Option Effectiveness advancement given in this thesis. In fact, it was this particular conflict which motivated the author to develop the Option Effectiveness approach. This trade dispute is divided into three phases in time. The first phase starts when China leads the initiative to establish the Asian Infrastructure Investment Bank (AIIB) and the US considers levying countermeasures. The second phase is when the US attempts to launch the Trans Pacific Partnership (TPP) agreement and offers China terms regarding the AIIB. In the case of China accepting the US conditions, the US will withdraw its opposition to the AIIB and announce a truce over it. The third phase is subsequent to the inauguration of Mr. Donald Trump as the President of the US in early 2017 and his withdrawal of the US from the TPP while China considers the launching of the Regional Comprehensive Economic Partnership (RCEP) trade agreement. The Option Effectiveness approach is further illustrated by applying it to three other conflicts: the Cuban Missile Crisis of 1962 and two environmental conflicts called the Elmira Groundwater Contamination conflict and the Garrison Diversion Unit irrigation dispute. The insights revealed by applying the Option Effectiveness approach to these conflicts, confirm the advantages of utilizing the Option Effectiveness method in conflict analysis.

Acknowledgements

I would like to sincerely thank my supervisors Prof. Keith W. Hipel and Prof. D. Marc Kilgour for their continuous support and guidance towards the successful completion of my Master of Applied Science Degree in Systems Design Engineering.

I would also like to extend my gratitude to the Custodian of the Two Holy Mosques King Salman Bin Abdulaziz Al Saud and the Government of Kingdom of Saudi Arabia for their generous scholarship which enabled me to pursue my Master's degree.

I would also like to thank Prof. L. Fang and Prof. H. R. Tizhoosh for acting as readers of my thesis and providing valuable suggestions for improving it.

Part of the content of my thesis is based upon two papers which were published in IEEE conference proceedings and are duly references at appropriate locations within my Master's thesis.

Gratitude is also extended to Mr. Robert Hart who provided the services of proofreading and editing, including correcting English errors and formatting.

Dedication

I would like to dedicate my work to my parents Jaweed Alhindi and Lubna Farooqui, my role-models, and my beloved wife Mominah Siddiqui who was there every day for me providing me with everlasting love, comfort and support to finish my master's degree.

Table of Contents

AUTHOR'S DECLARATION	ii
Abstract	iii
Acknowledgements	v
Dedication.....	vi
Table of Contents.....	vii
List of Figures	x
List of Tables.....	xi
List of Abbreviations	xvi
List of Symbols.....	xviii
Chapter 1 Introduction	1
1.1.1 Motivation	2
1.1.2 Research Objective	2
1.1.3 Thesis Structure	2
Chapter 2 Literature Review.....	5
2.1 Graph Model for Conflict Resolution	6
2.1.1 Fundamentals and Definitions of the Graph Model for Conflict Resolution	10
2.1.2 Solution Concepts within GMCR.....	12
2.2 Summary	15
Chapter 3 Methodology: Option Effectiveness	17
3.1 Strength of Equilibria	18
3.2 Option Effectiveness	22
3.3 Summary	24

Chapter 4 Shifting Paradigms in the Global Political and Economic Arena.....	26
4.1 The Emergence of the United States as a Global Superpower.....	26
4.1.1 The World Bank and the International Monetary Fund	31
4.2 China’s Rise and Its Emergence as a World Superpower in the 21 st Century.....	37
4.2.1 Chinese Global Economic Initiatives.....	41
4.3 Summary	43
Chapter 5 The Conflict Between China and the US over Global Trade Agreements..	45
5.1 Conflict Background	47
5.1.1 Implementation of AIIB prior to US Terms.....	48
5.1.2 Introduction of TPP and US Terms for China over the AIIB	49
5.1.3 Post-Obama Era and Implementation of RCEP	50
5.2 Methodology	51
5.3 Implementation of the Asian Infrastructure Investment Bank prior to United States Terms..	53
5.3.1 Conflict Model for First Phase.....	53
5.3.2 Stability Analysis of the First Phase	60
5.4 Introduction of the Trans Pacific Partnership agreement and the United States Terms for the Asian Infrastructure Investment Bank.....	63
5.4.1 Model of Second Phase.....	64
5.4.2 Stability Analysis of the Second Phase.....	69
5.4.3 Hypergame Investigation of the Second Phase	76
5.5 Post-Obama Era and Implementation of the Regional Comprehensive Economic Partnership	79
5.5.1 Model of Third Phase	80
5.5.2 Stability Analysis of the Third Phase.....	83
5.6 Options Effectiveness.....	86
5.6.1 First Phase Option Effectiveness	86
5.6.2 Second Phase Option Effectiveness	89

5.6.3 Third Phase Option Effectiveness.....	95
5.7 Overall Strategic Insights.....	97
5.8 Summary.....	101
Chapter 6 Option Effectiveness: Case Studies.....	103
6.1 Elmira Groundwater Contamination Conflict.....	103
6.1.1 The Conflict Model.....	104
6.1.2 Stability Analysis.....	107
6.1.3 Strength of Equilibria.....	110
6.1.4 Option Effectiveness.....	111
6.2 The Cuban Missile Crisis.....	113
6.2.1 The Conflict Model.....	115
6.2.2 Stability Analysis.....	116
6.2.3 Strength of Equilibria.....	118
6.2.4 Option Effectiveness.....	119
6.3 The Garrison Diversion Unit.....	121
6.3.1 The Conflict Model.....	122
6.3.2 Stability Analysis.....	127
6.3.3 Strength of Equilibria.....	133
6.3.4 Option Effectiveness.....	133
6.4 Summary.....	136
Chapter 7 Conclusions and Future Work.....	138
7.1 Future Work.....	139
Bibliography.....	140
Appendix A: Preferential Option Effectiveness.....	154

List of Figures

Figure 1.1 Thesis Outline	4
Figure 2.1 GMCR Procedure.....	7
Figure 3.1 Procedure for calculating the Option Effectiveness.....	18
Figure 3.2 Relationships among equilibrium types	21
Figure 5.1 SEQ stability analysis of state 5 with respect to China.....	69
Figure 5.2 SEQ stability analysis of state 5 with respect to the US	70
Figure 5.3 Historical evolution of the conflict over the three phases.....	99

List of Tables

Table 2.1 Basic solution concept descriptions and attributes (Fang et al., 1993).....	13
Table 3.1 Strength of Equilibria (Alhindi et al., 2018c), © 2018 IEEE	20
Table 3.2 Criteria for point assignment to each equilibrium state for measuring its strength (Alhindi et al., 2018c), © 2018 IEEE	22
Table 3.3 Tabular form of the Option Effectiveness approach (Alhindi et al., 2018c), © 2018 IEEE	24
Table 5.1 First phase DMs’ options	54
Table 5.2 First phase option form.....	56
Table 5.3 First phase option prioritization for each DM	58
Table 5.4 First phase preference ranking of states for China	59
Table 5.5 First phase preference ranking of states for the US.....	59
Table 5.6 First phase individual stability analysis with respect to China.....	62
Table 5.7 First phase individual stability analysis with respect to the US	62
Table 5.8 First phase stability analysis.....	63
Table 5.9 DMs’ options (Alhindi et al., 2017b), © 2017 IEEE.....	65
Table 5.10 China’s second phase option prioritization (Alhindi et al., 2017b), © 2017 IEEE	67
Table 5.11 The US’s second phase option prioritization (Alhindi et al., 2017b), © 2017 IEEE	67
Table 5.12 Second phase option form (Alhindi et al., 2017b), © 2017 IEEE.....	72
Table 5.13 Second phase standard individual stability analysis for China	73
Table 5.14 Second phase standard individual stability analysis for the US.....	74
Table 5.15 Second phase standard stability analysis – Equilibria (Alhindi et al., 2017b), © 2017 IEEE	75
Table 5.16 Second phase hypergame option form (Alhindi et al., 2017b), © 2017 IEEE ...	77

Table 5.17 Second phase hypergame individual stability analysis for China	77
Table 5.18 Second phase hypergame individual stability analysis for the US.....	78
Table 5.19 Second phase hypergame stability analysis – Equilibria (Alhindi et al., 2017b), © 2017 IEEE	79
Table 5.20 Third phase DMs’ options.....	80
Table 5.21 Third phase option form.....	82
Table 5.22 Third phase option prioritization.....	82
Table 5.23 Third phase preference ranking of states for China.....	83
Table 5.24 Third phase preference ranking of states for the US	83
Table 5.25 Third phase individual stability analysis for China.....	84
Table 5.26 Third phase individual stability analysis for the US	85
Table 5.27 Third phase stability analysis - Equilibria.....	85
Table 5.28 Strength of Equilibria calculation for the first phase GMCR model of the conflict between China and the US over global trade agreements	87
Table 5.29 Tabular approach for computing the Option Effectiveness for the first phase GMCR model of the conflict between China and the US over global trade agreements	89
Table 5.30 Strength of Equilibria calculation for the second phase standard GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE	90
Table 5.31 Tabular approach for computing the Option Effectiveness for the second phase standard GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE.....	91
Table 5.32 Strength of Equilibria calculation for the second phase hypergame GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE	93

Table 5.33 Tabular approach for computing the Option Effectiveness for the second phase hypergame GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE.....	94
Table 5.34 Strength of Equilibria calculation for the third phase GMCR model of the conflict between China and the US over global trade agreements.....	95
Table 5.35 Tabular approach for computing the Option Effectiveness for the third phase GMCR model of the conflict between China and the US over global trade agreements.....	97
Table 5.36 Evolution of the conflict over the three phases.....	99
Table 6.1 Option form of the Elmira Groundwater water contamination conflict.....	105
Table 6.2 Preference ranking of MoE in the Elmira groundwater water contamination conflict.....	105
Table 6.3 Preference ranking of Uniroyal in the Elmira groundwater water contamination conflict.....	106
Table 6.4 Preference ranking of Local Governments in the Elmira groundwater water contamination conflict.....	106
Table 6.5 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to MoE.....	107
Table 6.6 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to Uniroyal.....	108
Table 6.7 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to Local Governments.....	109
Table 6.8 Stability analysis of the Elmira groundwater water contamination conflict showing the equilibrium states.....	110
Table 6.9 Strength of Equilibria calculation of the Elmira groundwater water contamination conflict model.....	111
Table 6.10 Option Effectiveness calculation of the Elmira groundwater water contamination conflict model.....	112

Table 6.11 Option form of the Cuban missile crisis conflict.....	115
Table 6.12 Preference ranking of the US in the Cuban missile crisis conflict.....	116
Table 6.13 Preference ranking of the USSR in the Cuban missile crisis conflict	116
Table 6.14 Individual stability analysis of the Cuban missile crisis conflict with respect to the US	117
Table 6.15 Individual stability analysis of the Cuban missile crisis Conflict with respect to the USSR	117
Table 6.16 Stability analysis of the Cuban missile crisis conflict showing the equilibrium states	118
Table 6.17 Strength of Equilibria calculation of the Cuban missile crisis conflict model .	119
Table 6.18 Option Effectiveness calculation of the Cuban Missile Crisis conflict model .	120
Table 6.19 The possible options available for the decision makers in the Garrison Diversion Unit conflict (Fraser & Hipel, 1984)	124
Table 6.20 Option form of the Garrison Diversion Unit conflict.....	125
Table 6.21 Preference ranking of US Support, US Opposition, Canadian Opposition, and IJC in the Garrison Diversion Unit conflict	126
Table 6.22 Individual stability analysis of the Garrison Diversion Unit conflict with respect to US Support	128
Table 6.23 Individual stability analysis of the Garrison Diversion Unit conflict with respect to US Opposition	129
Table 6.24 Individual stability analysis of the Garrison Diversion Unit conflict with respect to Canadian Opposition	130
Table 6.25 Individual stability analysis of the Garrison Diversion Unit conflict with respect to IJC	131
Table 6.26 Stability analysis of the Garrison Diversion Unit conflict showing the equilibrium states.....	132

Table 6.27 Strength of Equilibria calculation of the Garrison Diversion Unit conflict model	133
Table 6.28 Option Effectiveness calculation of the Garrison Diversion Unit conflict model	136
Table 6.29 Option importance ranking in the Garrison Diversion Unit conflict model.....	136
Table A.1 Tabular form of Preferential Option Effectiveness approach for DM i	156

List of Abbreviations

ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
B&R	Belt and Road
Canadian Opposition	Canadian Opposition to Garrison
DM	Decision Maker
FCP	French Communist Party
GDN	Garrison Diversion Unit
GMCR	Graph Model for Conflict Resolution
GMR	General Metarationality
IJC	International Joint Commission
IMF	International Monetary Fund
Local Governments	The Regional Municipality of Waterloo and the Township of Woolwich
MoE	Ontario Ministry of Environment
NDMA	N-Nitroso Dimethylamine
OBOR	One Belt One Road
RCEP	Regional Comprehensive Economic Partnership
SEQ	Sequential Stability

SMR	Symmetric Metarationality
TPP	Trans Pacific Partnership
UI	Unilateral Improvement
UM	Unilateral Move
UN	United Nations
Uniroyal	Uniroyal Chemical Ltd
US	United States
US Opposition	United States Opposition to Garrison
US Support	United States Support for Garrison
USSR	Soviet Union
WTO	World Trade Organization
WWI	World War One
WWII	World War Two

List of Symbols

\succeq_i	Set of binary relations on \mathcal{S} that express DM i 's preferences over \mathcal{S}
λ	Total number of options in a conflict model
$A_i(k)$	Set of allowable state transitions or UMs for DM i from k to another state in one step, where $k \in \mathcal{S}$.
$A_{\mathbf{N}\setminus\{i\}}$	The set of UMs for all the DMs except i from k , where $k \in \mathcal{S}$
$A_i^+(k)$	The set of UIs for DM i from k , where $k \in \mathcal{S}$.
$A_{\mathbf{N}\setminus\{i\}}^+(k)$	The set of UIs for all the DMs except i from k , where $k \in \mathcal{S}$
a_{ym}	A binary function which shows if the m^{th} option under E_y is selected or not. The value of the function is 1 when the option is selected and 0 otherwise
\mathbf{E}	Set of all equilibria in a conflict model
E_y	Equilibrium y in \mathbf{E}
E	An equilibrium state in \mathbf{E}
$EFF(O_m)$	Option m 's effectiveness in a conflict
$EFF_{PREF_{DM_i}}(O_m)$	Option m 's preferential effectiveness with respect to DM i
f	A state's mapping function represented by λ -dimensional column vector

G	The graph model of a conflict
G_i	A directed graph for DM i
$g_1^{s_1}$	DM 1's strategy associated with State s_1
$g_i^{s_1}$	DM i 's strategy associated with State s_1
$g_n^{s_1}$	DM n 's strategy associated with State s_1
i	DM in a conflict model
k	State k in \mathcal{S}
M_i	Total number of options available for DM i
M	Total number of options available in a conflict model
m	The m^{th} option in a conflict model
N	Set of DMs in a conflict model
n	Total number of DMs in a conflict model
O	Set of options for all DMs in a conflict model
O_i	Set of options available in the conflict for each DM i in a conflict model
O_m	The m^{th} option in O
$o_{\bar{k}}^i$	\bar{k}^{th} option for DM i
$O(E_y)$	Set of options for equilibrium state y
S₀	Status quo in a conflict model

\mathcal{S}	Set of states or scenarios in a conflict model
\mathcal{S}_i^{Nash}	The set of Nash stable states for DM i
\mathcal{S}_i^{SEQ}	The set of Sequentially stable states for DM i
\mathcal{S}_i^{GMR}	The set of general metarational states for DM i
\mathcal{S}_i^{SMR}	The set of symmetric metarational states for DM i
s	A state within \mathcal{S}
$STR(E)$	Numerical representation of an equilibrium state's strength
$STR_{PREF_{DM_i}}(E)$	Numerical representation of an equilibrium state's preferential strength with respect to DM i
t	A state within \mathcal{S}
$t_{GMR}(E)$	A binary function which shows if E is a GMR equilibrium. The value of the function is 1 when it is true and 0 otherwise
$t_{Nash}(E)$	A binary function which shows if E is a Nash equilibrium. The value of the function is 1 when it is true and 0 otherwise
$t_{SEQ}(E)$	A binary function which shows if E is a SEQ equilibrium. The value of the function is 1 when it is true and 0 otherwise
$t_{SMR}(E)$	A binary function which shows if E is a SMR equilibrium. The value of the function is 1 when it is true and 0 otherwise
v	State v in \mathcal{S}

- y The y^{th} equilibrium state
- Y The total number of equilibria in a conflict model

Chapter 1

Introduction

Every day, countries and individuals participate in negotiations and conflicts. These conflicts, for instance, can be of an economic, military, or corporate nature. Analyzing such conflicts educates decision-makers (DMs) about a dispute, permitting them to think strategically and thereby helping in making more calculated decisions. The Graph Model for Conflict Resolution (GMCR) approach has been shown to be a reliable and valuable method to analyze disputes and conflicts involving two or more DM (Fang, Hipel, & Kilgour, 1993; Fang, Hipel, Kilgour, & Peng, 2003a, 2003b; Kilgour & Hipel, 2005, 2010; Kinsara, Petersons, Hipel, & Kilgour, 2015b; Xu, Hipel, Kilgour, & Fang, 2018).

For example, the strategic investigation of the military and political conflict between the United States (US) and the Soviet Union (USSR), formally known as the Cuban Missile Crisis (Fraser & Hipel, 1982, 1984; Hipel, 2011), using GMCR methodology has shown the GMCR approach's capabilities in predicting the possible outcomes of a conflict. Another illustration can be the water conflict over the Euphrates River between Syria, Iraq, and Turkey, which demonstrates the GMCR methodology and adds the concept of the inverse GMCR approach (Kinsara, Kilgour, & Hipel, 2015a). However, up till now, the GMCR approach has been focused on analyzing conflicts at the level of states or scenarios. The option effectiveness approach, a novel method presented in this thesis, allows a detailed investigation of the conflict model at the option level, in turn allowing a DM to better

understand the options or the actions needed to define states, and comprehend the consequences of selecting an option which a DM controls, thereby possibly resolving the conflict in its favor.

1.1.1 Motivation

Analysis of the economic conflict between China and the US over global trade agreements has shown that the conflict can be influenced to end in a more desirable resolution by adding appropriate options (Alhindi, Hipel, & Kilgour, 2018b). Therefore, understanding the way each option works in a conflict can add valuable insights for a DM, which would ultimately aid him or her in choosing the best option to end the conflict at a preferred scenario.

1.1.2 Research Objective

The purpose of this thesis is to introduce a new method which allows DMs and analysts to investigate a conflict model at the option level, rather than just investigating it at the state level of the conflict. This novel approach is named “Option Effectiveness”, which computes the effectiveness of each option in a conflict. It can also be useful, for instance, in classifying the equilibria or resolutions of a conflict according to the utilization of the primary options as suggested by Fang et al. (2003a, 2003b).

1.1.3 Thesis Structure

The thesis is divided into seven chapters. Chapter 1 discusses the GMCR approach generally and states the motivation of the study, while the basics and fundamentals of the GMCR methodology are reviewed in Chapter 2. Chapter 3 introduces the Option Effectiveness

approach as an extension to GMCR methodology, while Chapter 4 highlights the economic politics of the US and China and the global economic aftermath of World War II. The conflict between China and the US over global trade agreements, demonstrating the GMCR methodology and the Option Effectiveness approach, are explained in Chapter 5. Evaluation of the Option Effectiveness procedure is carried out in Chapter 6 by applying it to important real-world conflict models. The conclusions of the research and future work possibilities are discussed in Chapter 7. Figure 1.1 portrays the connections among the chapters and the contents of the thesis.

Finally, this thesis contains some of the author's work, both published and submitted for publication, which includes "The Conflict Over the Asian Infrastructure Investment Bank Involving China, USA, and Japan" (Alhindi, Hipel, & Kilgour, 2017b) © 2017 IEEE; "A Measure for Option Effectiveness in the Graph Model for Conflict Resolution" (Alhindi, Hipel, & Kilgour, 2018a); "The Conflict over Global Trade Agreements Between China and the United States" (Alhindi et al., 2018b); and "Option Effectiveness in Conflict Resolution" (Alhindi, Kilgour, & Hipel, 2018c) © 2018 IEEE.

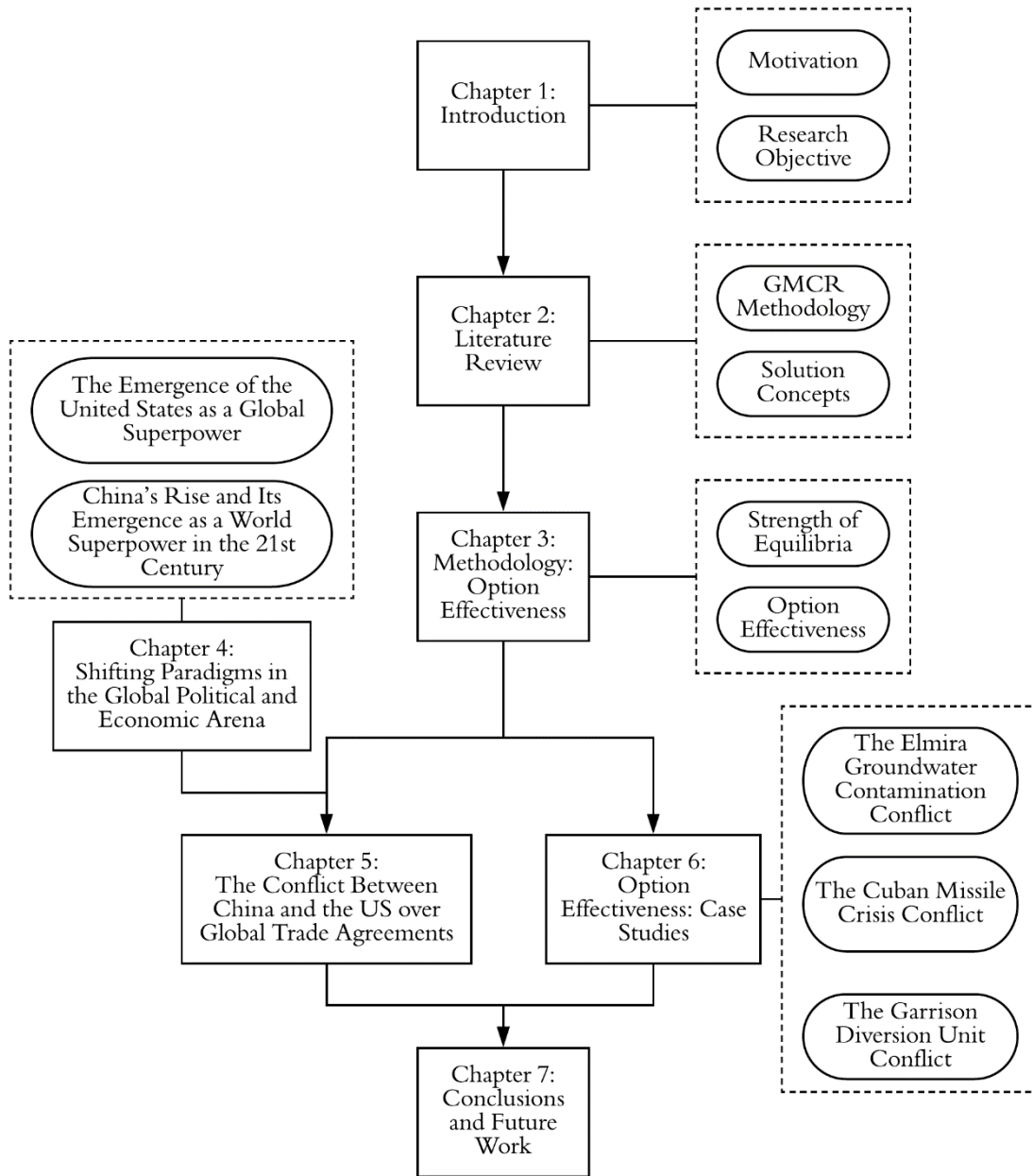


Figure 1.1 Thesis Outline

Chapter 2

Literature Review

Conflicts are inevitable when interests of the Decision Makers (DMs) differ. A conflict has been defined as a situation involving two or more parties in a dispute over an issue or resource (Fraser & Hipel, 1984). Because no extensive modeling approach mimicking real conflict, allowing for better understanding between involved parties, and helping decision makers (DMs) make better judgements exists, a Conflict Analysis methodology was proposed by Fraser and Hipel (1979, 1984). A subsequent advancement in the field of conflict analysis named Graph Model for Conflict Resolution (GMCR) was later proposed by Kilgour, Hipel, and Fang (1987). Conflict investigation is crucial for analysts and DMs because of the increased social and political implications of decisions (Fraser & Hipel, 1984). One needs to fully understand the hypothetical consequences of a decision before executing it.

GMCR analyzes and predicts conflict outcomes, and can handle all conflicts, including economic, military, or corporate (Fang et al., 1993; Kilgour & Hipel, 2005; Kilgour & Hipel, 2010; Alhindi, Hipel, & Kilgour, 2017a, 2017b; Xu et al., 2018). Typically, a conflict model, using GMCR, specifies the DMs relevant to the conflict, the options each DM controls, and the preference ranking for each DM (i.e., a ranking of scenarios according to DM's preference for how the conflict should end) (Fang et al., 1993; Kilgour & Hipel, 2005). The following sections explain these GMCR fundamentals.

2.1 Graph Model for Conflict Resolution

The GMCR methodology requires a sound understanding of the conflict. The conflict needs to be examined as a whole rather than a series of discrete events. It consists of two main stages: modeling and analysis (Kilgour et al., 1987; Fang et al., 1993; Kilgour & Hipel, 2005).

Fig 2.1 based on Hipel & Walker (2011) shows the GMCR procedure which includes the following steps:

- 1) Identification of both the point in time at which the conflict is analyzed and the DMs in the conflict.
- 2) Identification of the feasible scenarios, or states that may occur, in the conflict because of option combinations available to the DMs. Options are also identified as reversible or irreversible.
- 3) Elimination of any infeasible option combinations from the model, based on conditions such as mutually exclusive options, specifying that at least one option must be chosen within a set of options, dependency among options, or any other kind of infeasibility that could arise (Fang et al., 2003a, 2003b). Then the allowable transitions between feasible states are identified.

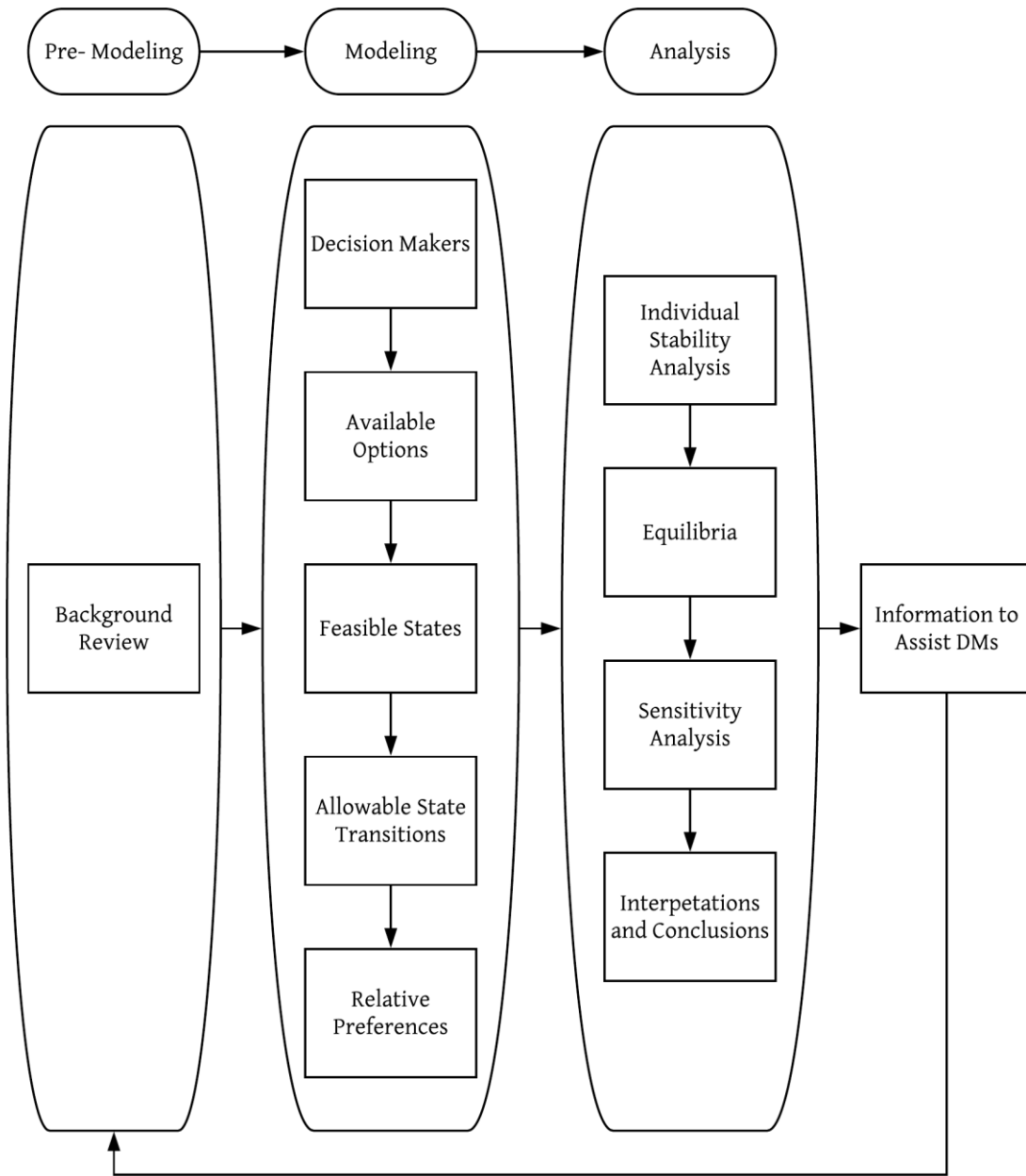


Figure 2.1 GMCR Procedure

- 4) Establishment of each DM's relative preference over the feasible states. As a consequence, unilateral improvements (UIs) and unilateral moves (UMs) can be determined. UIs constitute allowable moves to preferred states, as compared to the initial state; UMs constitute allowable moves from the initial state to another state, regardless of preference.

After the fourth step of the modeling stage, the conflict model is ready for the analysis stage. The analysis stage can be summarized as follows:

- 1) Individual stability analysis: This step is achieved by applying a variety of solution concepts, including Nash stability (Nash, 1950; Nash, 1951), sequential (SEQ) stability (Fraser & Hipel, 1979, 1984), general metarational (GMR) stability (Howard, 1971), and symmetric metarational (SMR) stability (Howard, 1971). It identifies the stability of each state in the model for each DM.
- 2) Equilibrium identification: The information gathered from the individual stability analysis determines the equilibrium states. An equilibrium state is a state that is stable for all DMs in the model under a given solution concept. For instance, if there are two DMs, A and B, and if State S_1 is stable for both A and B under SEQ stability then State S_1 is an equilibrium under the SEQ stability definition.
- 3) Sensitivity analysis: sensitivity analysis can be performed on a GMCR model by changing, for example, the preference ranking of the states for a given DM, or by adding or removing options.

- 4) Conclusions: The stability analysis and the sensitivity analysis help to form a strategic understanding of the conflict, including how it may evolve and where it will resolve. This understanding allows the DM to calculate the relative benefit of moving from the current state.

Analyzing a conflict allows DMs to make better informed actions based on conclusions drawn from the conflict analysis. The advantages of such analysis are listed below:

- 1) It permits a realistic and objective approach that analyzes complex situations based on information retained and structured in the premodeling and modeling stages
- 2) It provides an easy and effective medium for communicating a conclusion about the dispute.
- 3) It determines the gaps where further information is required.
- 4) It draws implications and conclusions from the information that was acquired during the conflict investigation.
- 5) It provides clarity to the analyst or the DMs, regarding situational clarity and the determination of a desirable course of action.

(Fraser & Hipel, 1984, p. 8)

Although the GMCR approach is simple, it is time-consuming in manual investigations of large disputes. Software such as GMCR II (Hipel, Kilgour, Fang, & Peng, 1997; Fang et al., 2003a, 2003b) and GMCR+ (Kinsara et al., 2015b) applies the GMCR methodology on real-

world conflicts and permits an easy-to-use automated approach for the understanding and analysis of complex conflicts.

2.1.1 Fundamentals and Definitions of the Graph Model for Conflict Resolution

The GMCR methodology was first introduced by Kilgour, Hipel, and Fang (1987). The methodology revolves around certain fundamental ideas and definitions that are explained below. They are derived from Kilgour et al. (1987) and Kilgour & Hipel (2010).

- Decision-makers: the set of DMs is represented by \mathbf{N} , satisfying $2 \leq n = |\mathbf{N}| < \infty$. The set \mathbf{N} is usually written $\mathbf{N} = \{1, 2, \dots, i, \dots, n\}$.
- Options: the set of options available in the conflict for each DM i in \mathbf{N} is represented as $O_i = \{o_{\bar{k}}^i : \bar{k} = 1, 2, \dots, M_i\}$, where $o_{\bar{k}}^i$ is the \bar{k}^{th} option for DM i and M_i is the total number of options available for DM i .

Moreover, the set of options for all DMs in \mathbf{N} is denoted by $O = \cup_{i \in \mathbf{N}} O_i$.

- Strategy: The set of strategies for each DM i is expressed by mapping function $g_i : O_i \rightarrow \{0, 1\}$, where for each option $\bar{k} = 1, 2, \dots, M_i$,

$$g_i(o_{\bar{k}}^i) = \begin{cases} 1, & \text{if DM } i \text{ selects } o_{\bar{k}}^i \\ 0, & \text{otherwise} \end{cases}$$

- States: The set of states is expressed by $\mathbf{S} = \{s_1, s_2, \dots, s_{2^\lambda}\}$, where $2 \leq M = |\mathbf{S}| < \infty$, M is the total number of options available in the model and 2^λ is the total number of states in the model (and will be explained later). Moreover, the status quo state is

represented by \mathbf{S}_0 . Note that a state can be represented by a mapping function $f : O \rightarrow \{0, 1\}$ such that,

$$f(o_k^i) = \begin{cases} 1, & \text{if DM } i \text{ selects } o_k^i, \\ 0, & \text{otherwise} \end{cases} \quad \text{for } i = 1, 2, \dots, n$$

Therefore, a state is expressed by a λ -dimensional column vector, where λ is the total number of options in O . Moreover, a state is defined by the λ -dimensional column vector in the form of $(f(o_1^1), f(o_2^1), \dots, f(o_{M_1}^1), \dots, f(o_1^n), f(o_2^n), \dots, f(o_{M_n}^n))^T$. The total number of mathematically possible states in a model is 2^λ , where $\lambda = |O|$, since each option in O can either be selected or not by the DM i controlling it. Usually, one can eliminate some states based on conditions such as mutual exclusivity of options, requiring that at least one option must be selected in the scenarios, option dependency on other options, and any other type of infeasibility that could occur (Fang et al., 2003a, 2003b). The eliminated states constitute infeasible states, whereas the states that survived the elimination process are feasible states. The DMs' strategies associated with s_1 are represented as $g_1^{s_1}, g_2^{s_1}, \dots, g_i^{s_1}, \dots, g_n^{s_1}$; for $\mathbf{N} = \{1, 2, \dots, i, \dots, n\}$. Thus, states s_1 is represented by $s_1 = \left((g_1^{s_1})^T, (g_2^{s_1})^T, \dots, (g_i^{s_1})^T, \dots, (g_n^{s_1})^T \right)^T$.

- **Relative Preferences:** For each DM i in \mathbf{N} , \succeq_i is a complete set of binary relations on \mathbf{S} that express DM i 's preferences over \mathbf{S} . Therefore, if $s, t \in \mathbf{S}$ then $s \succeq_i t$ indicates that s is more preferred than t for DM i or that DM i equally prefers s to t . Following a standard convention, DM i firmly prefers s to t , which is mathematically expressed as s

$\succ_i t$, iff $s \succeq_i t$ but $\neg [t \succeq_i s]$. Moreover, the statement that DM i is indifferent between s and t , or that DM i equally prefers s to t , is represented $s \sim_i t$; it is valid if both $s \succeq_i t$ and $t \succeq_i s$.

- Transitions: For each DM i in \mathbf{N} , a directed graph is represented by $G_i = (S, A_i)$ where the arc set $A_i \subseteq \mathbf{S} \times \mathbf{S}$. The arc set A_i does not contain loops because any entry $(s, t) \in A_i$ has the property $s \neq t$. Moreover, the entries or values of $A_i(k)$, such that $k \in \mathbf{S}$, are state transitions or UMs controlled by DM i from k . The set of UIs for DM i from k is denoted by $A_i^+(k)$ where $k \in \mathbf{S}$.
- Graph model: the graph model of a conflict is represented by Equation 2.1.

$$\mathbf{G} = \langle \mathbf{N}, \mathbf{S}, \{A_i : i \in \mathbf{N}\}, \{\succeq_i : i \in \mathbf{N}\} \rangle \quad (2.1)$$

2.1.2 Solution Concepts within GMCR

Solution concepts are a key part of the GMCR methodology, specifically for the analysis stage. This section elaborates the attributes and properties of the solution concepts. Table 2.1 is derived from a table mentioned in “Interactive Decision Making: The Graph Model for Conflict Resolution” published by Fang et al. (1993) and summarizes the key attributes of the solution concepts.

2.1.2.1 Nash Stability

Nash stability revolves around the idea that a DM will always choose the alternative that yields the most preferred possible scenario. Nash stability is formally defined in Definition

2.1 (Nash, 1950; Nash, 1951; Fang, Hipel, & Kilgour, 1989; Fang et al., 1993; Xu et al., 2018). State k is Nash stable, in a n -DM model where $n > 2$, for DM i iff i does not have any UIs to move to a more preferred state from k . The Nash solution concept considers only one move in the future, requires self-knowledge of preferences, and ignores all strategic risks.

Definition 2.1 Let $i \in \mathbf{N}$. A state is Nash stable for DM i , denoted by $k \in \mathcal{S}_i^{Nash}$, iff $A_i^+(k) = \emptyset$.

Table 2.1 Basic solution concept descriptions and attributes (Fang et al., 1993)

Solution Concepts	Description	Foresight (Future Steps)	Knowledge of Preferences	Dis-improvement	Strategic Risk
Nash Stability	Principal DM can't move unilaterally to a more preferred state	1	Own	Never	Ignores risk
Sequential Stability (SEQ)	Opponents' unilateral improvements sanction all concerned DM's unilateral improvements	2	All	Never	Takes some risks; satisfice
Symmetric Metarationality (SMR)	Opponents' unilateral moves sanction all principal DM's unilateral improvements, even after response by the principal DM	3	Own	By opponents' sanctions	Avoids risks
General Metarationality (GMR)	Opponents' unilateral moves sanction all concerned DM's unilateral improvements	2	Own	By opponents' sanctions	Avoids risk

2.1.2.2 Sequential Stability

The SEQ stability concept is formally expressed by Definition 2.2 (Fang et al., 1993; Xu et al., 2018). In an n -DM model where $n > 2$, state k is SEQ stable for DM i if all the opposing

DMs $\mathbf{N}\{i\}$ can sanction all the UIs of i from k using UIs that will move $\mathbf{N}\{i\}$ to a more preferred state v , where v is less preferred for i than k . SEQ stability considers two steps in the future, requires knowledge of self and opponent's preference rankings, and satisfies the focal DM with respect to the outcomes.

Definition 2.2 For $i \in \mathbf{N}$, a state is sequentially stable (SEQ) for DM i , expressed as $k \in \mathcal{S}_i^{SEQ}$, iff for every $k_1 \in A_i^+(k)$, there exists at least one $k_2 \in A_{\mathbf{N}\{i\}}^+(k_1)$ with $k \succeq_i k_2$.

2.1.2.3 General Metarational Stability

The GMR solution concept is formally defined in Definition 2.3 (Howard, 1971; Fang et al., 1989; Fang et al., 1993; Xu et al., 2018) which explains that state k , in an n -DM model where $n > 2$, is GMR stable for DM i if all the remaining DMs $\mathbf{N}\{i\}$ can sanction all the UIs of i from k by UMs to another state v which is less preferred for i than k . GMR stability is similar to SEQ stability; however, it does not require UIs for the DMs $\mathbf{N}\{i\}$. GMR stability considers two moves in the future, requires knowledge of self-preference rankings only, and avoids all risks.

Definition 2.3 For $i \in \mathbf{N}$, a state is general metarational (GMR) for DM i , denoted by $k \in \mathcal{S}_i^{GMR}$, iff for every $k_1 \in A_i^+(k)$ there exists at least one $k_2 \in A_{\mathbf{N}\{i\}}(k_1)$ with $k \succeq_i k_2$.

2.1.2.4 Symmetric Metarational Stability

The SMR solution concept is formally described in Definition 2.4 (Howard, 1971; Fang et al., 1989; Fang et al., 1993; Xu et al., 2018). This stability definition is similar to GMR but with an addition that allows the focal DM to consider an alternative to escape harm caused

by the opponents' sanction. Thus, state k in a n -DM model, where $n > 2$, is SMR stable iff DMs $\mathbf{N} \setminus \{i\}$ can sanction all the UIs of i from k using UMs to another state v , such that v is less preferred for i than k , and such that there are no UIs for i to escape from v . SMR stability studies three moves in the future, requires knowledge of self-preference rankings, and avoids all risks.

Definition 2.4 For $i \in \mathbf{N}$, a state is symmetric metarational (SMR) for DM i denoted by $k \in \mathbf{S}_i^{SMR}$, iff for every $k_1 \in A_i^+(k)$ there exists at least one $k_2 \in A_{\mathbf{N} \setminus \{i\}}(k_1)$, such that $k \succeq_i k_2$ and $k \succeq_i k_3$ for all $k_3 \in A_i(k_2)$.

When stability has been determined for every state for all the DMs, the equilibria of the model follow. A state is an equilibrium under a stability concept if it is stable under that stability concept for all the DMs in the conflict. This idea can be expressed formally as in Definition 2.5

Definition 2.5 A state $k \in \mathbf{S}$ is an equilibrium state under a specific solution concept, if k is stable for all DMs in the model under the same solution concept. \mathbf{E} is the set of all equilibria in the conflict.

If $E \in \mathbf{E}$ then the values of $t_{Nash}(E)$, $t_{SEQ}(E)$, $t_{SMR}(E)$, $t_{GMR}(E)$ identify the type of equilibrium. See Chapter 3 for details.

2.2 Summary

The GMCR methodology is a well-established tool for analyzing real world disputes and predicting its possible resolutions. A conflict model within the GMCR approach constitutes

mainly of relative DMs in the conflict and the options they control, a set of feasible states, and the state preference order of the DMs in the conflict. It analyzes the conflict based on solution concepts, or behaviors under conflict, such as Nash, SEQ, SMR and GMR. The GMCR approach enhances the DMs understanding of the conflict and allows them to take more informed decisions in resolving conflicts.

Chapter 3

Methodology: Option Effectiveness

The GMCR approach has been shown to be a robust and effective method to analyze disputes and conflicts involving two or more DMs (Fang et al., 1993; Xu et al., 2018). Previous studies conducted by Alhindi et al. concluded that options could, in fact, be used as means to influence the conflict and reach a more desirable resolution (Alhindi et al., 2017a, 2017b, 2018b). Therefore, knowing the effectiveness and importance of the options available at hand for the DMs would allow a better understanding of the conflict's direction and where it is heading in order to resolve it. The present research proposes a novel approach to measure options effectiveness which relies on stability analysis using GMCR (Alhindi et al., 2018a, 2018c). This approach is only usable subsequent to the stability analysis. GMCR model has to be used first in order to conduct Nash, SEQ, GMR, and SMR Stability analyses of the conflict, which will identify the equilibria states. Then, the strength of each equilibrium state can be calculated. The strengths of the equilibria are then used to measure the option effectiveness. The following subsections explain the method of calculating the strength of an equilibrium and the option effectiveness. The procedure for Option Effectiveness is delineated in Fig. 3.1.

This chapter includes published contents from “A Measure for Option Effectiveness in the Graph Model for Conflict Resolution” (Alhindi et al., 2018a) and “Option Effectiveness in Conflict Resolution” (Alhindi et al., 2018c) © 2018 IEEE.

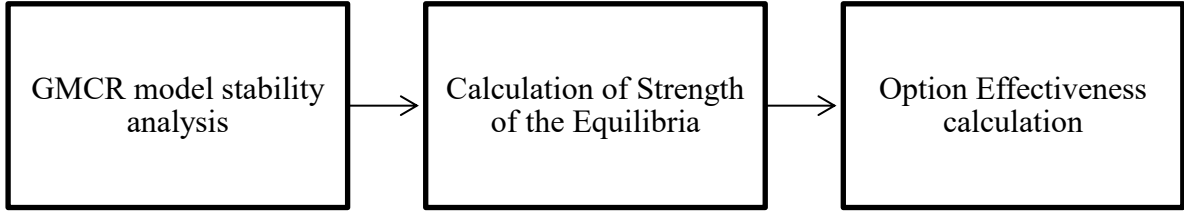


Figure 3.1 Procedure for calculating the Option Effectiveness

3.1 Strength of Equilibria

For measuring the strength of the identified equilibria, a simple weighting technique is proposed. This approach is inspired by the work of Matbouli, Kilgour, and Hipel (2015) in measuring the robustness of an equilibrium. The strength of each equilibrium is calculated by assigning weight points for each equilibrium state according to the solution concept that has identified it as being an equilibrium. Certain fundamentals of GMCR are defined before calculating the strength of the equilibria:

- Equilibrium States: Let the set of all equilibria in a conflict be represented by $E = \{E_1, E_2, \dots, E_y, \dots, E_Y\}$, where E_y is the y^{th} equilibrium state and Y is the total number of equilibrium states in a conflict.
- Equilibrium State representation in terms of the solution concepts: an equilibrium state E_y is represented by the set $E_y = (t_{Nash}, t_{SEQ}, t_{SMR}, t_{GMR})$, where:

$$t_{Nash} = \begin{cases} 1, & \text{if } E_y \text{ is an equilibrium under Nash} \\ 0, & \text{otherwise} \end{cases},$$

$$t_{SEQ} = \begin{cases} 1, & \text{if } E_y \text{ is an equilibrium under SEQ} \\ 0, & \text{otherwise} \end{cases},$$

$$t_{SMR} = \begin{cases} 1, & \text{if } E_y \text{ is an equilibrium under SMR} \\ 0, & \text{otherwise} \end{cases},$$

$$t_{GMR} = \begin{cases} 1, & \text{if } E_y \text{ is an equilibrium under GMR} \\ 0, & \text{otherwise} \end{cases}$$

Once all the equilibria states are defined with respect to the stability concepts, one can calculate the strength of an equilibrium state E by using Equation 3.1

$$STR(E_y) = [(t_{Nash} \times 4) + (t_{SEQ} \times 3) + (t_{SMR} \times 2) + (t_{GMR} \times 1)] \quad (3.1)$$

Therefore, $STR(E_y)$ is a numerical representation of the equilibrium strength. In this approach, the Nash equilibrium is considered the strongest solution concept, and is given four points since there are no UIs by which the focal DM can consider moving to a more preferred state. The SEQ equilibrium has been ranked 2nd in terms of equilibria strength and is assigned three points because the UIs of the focal DM can be sanctioned by UIs from the opponent. The 3rd-ranked equilibrium is SMR, which is allotted two points, as it allows the focal DM the chance to escape the opponent's sanction. The weakest equilibrium states are the ones which are GMR equilibrium and they are given one point, because the GMR stability considers the UMs only for the focal DM and for the opponent by which he or she can sanction the focal DM's UMs, and unlike the SMR stability, GMR stability does not allow the chance to escape a sanction. It can be noticed that the strength of an equilibrium state cannot exceed 10 points. A tabular representation for calculating the equilibrium is proposed

which makes it easier for an analyst to perform the calculation and the comparison among the equilibria. Table 3.1, which is named “Equilibrium Strength”, shows the proper structure of the tabular representation of the equilibrium strength calculation in GMCR. The equilibria of the model are listed row-wise below the “Equilibrium” heading in Table 3.1. The equilibrium representations, in terms of the solution concepts, are listed from the 2nd to the 5th column of the table. The last column in Table 3.1 shows the strength of the equilibrium state which is calculated by Equation 3.1. Furthermore, Table 3.2 summarizes the points allocation criteria for the equilibrium state with respect to the solution concepts that found the state as an equilibrium.

Table 3.1 Strength of Equilibria (Alhindi et al., 2018c), © 2018 IEEE

<i>Equilibrium</i>	<i>Equilibrium representation using the solution concepts</i>				<i>Strength of Equilibrium</i>
	<i>Nash (4)</i>	<i>SEQ (3)</i>	<i>SMR (2)</i>	<i>GMR (1)</i>	
E_1	$t_{Nash}(E_1)$	$t_{SEQ}(E_1)$	$t_{SMR}(E_1)$	$t_{GMR}(E_1)$	$STR(E_1)$
E_2	$t_{Nash}(E_2)$	$t_{SEQ}(E_2)$	$t_{SMR}(E_2)$	$t_{GMR}(E_2)$	$STR(E_2)$
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots
E_Y	$t_{Nash}(E_Y)$	$t_{SEQ}(E_Y)$	$t_{SMR}(E_Y)$	$t_{GMR}(E_Y)$	$STR(E_Y)$

A state that has been identified as Nash equilibrium is also considered SEQ, SMR, and GMR equilibrium, while a state that is SEQ equilibrium is also recognized as GMR equilibrium and often, but not always, as SMR equilibrium. Moreover, a state that is SMR equilibrium is always a GMR equilibrium too. Figure 3.2, which is based on a figure in an

article authored by Fang et al. (1989), shows a Venn diagram that illustrates the aforementioned relationships among the equilibrium types.

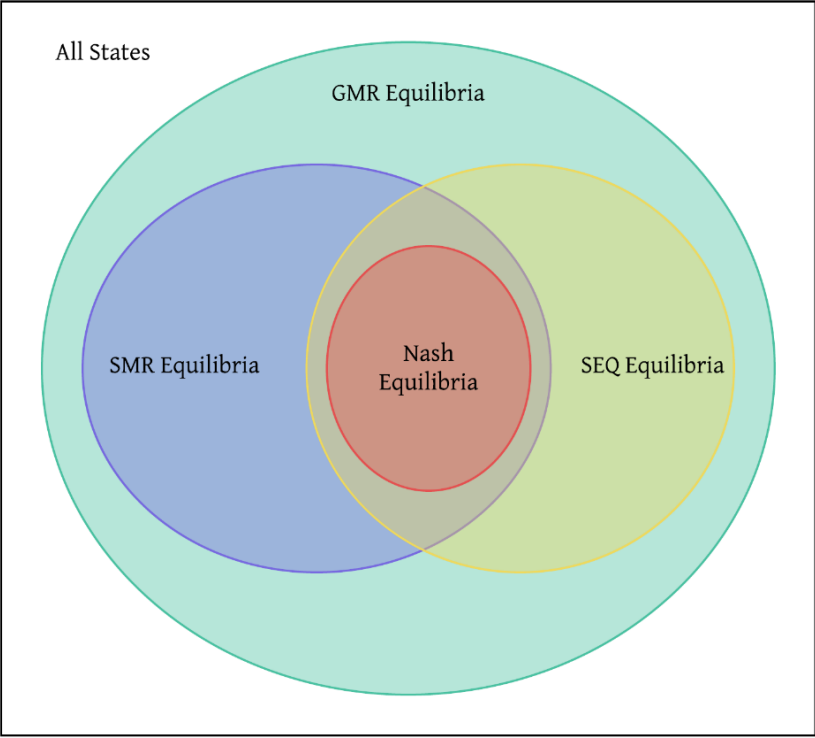


Figure 3.2 Relationships among equilibrium types

Table 3.2 Criteria for point assignment to each equilibrium state for measuring its strength (Alhindi et al., 2018c), © 2018 IEEE

Solution concept that identified the state as an equilibrium	Points allotted	Explanation
Nash	4	4 strength points are given if the state is found to be Nash equilibrium
SEQ	3	3 strength points are assigned if the state is found to be SEQ equilibrium
SMR	2	2 strength points are allocated if the state is found to be SMR equilibrium
GMR	1	1 strength point is given if the state is found to be GMR equilibrium

3.2 Option Effectiveness

The information gained by calculating the strength of the equilibria allows a general understanding of the conflict and the possibility of an equilibrium to occur in real life. Moreover, it is also of great importance to understand the conflict at the option level, since the options are the basic unit on which a GMCR model is built. The Option Effectiveness aims to provide information about the contribution of each option towards the equilibria of the model, which would ultimately help the DMs to understand the conflict better and allow them to rank the options in terms of their effectiveness and importance in a dispute. However, prior to the Option Effectiveness calculation, certain fundamentals must be defined:

- Set of options in a conflict model: the set of options is $\{O_1, O_2, \dots, O_m, \dots, O_M\}$.
- Options of an equilibrium: Equilibrium state E_y can be expressed as

$$E_y = \{a_{y1}, a_{y2}, \dots, a_{ym}, \dots, O_{yM}\} \text{ where}$$

$$a_{ym} = \begin{cases} 1, & \text{if Option } m \text{ is selected} \\ 0, & \text{otherwise} \end{cases},$$

E_y is the equilibrium state, O_m is the m^{th} option, which may be selected or not under E_y , and M is the total number of options available.

Once the strengths of the equilibria have been calculated and the aforementioned fundamentals established, one can calculate the effectiveness of each option. The procedure is to sum up the strengths of the equilibrium states used to select a given option. A tabular representation is suggested in order to ease the process of Option Effectiveness computation. Table 3.3 is a general representation of the Option Effectiveness calculation where the equilibrium states are listed row-wise and the options are listed column-wise. The last column of the table shows the strength of the equilibria row-wise, calculated by Equation 3.1, and the last row shows the Option Effectiveness column-wise. In Table 3.3

The option effectiveness, denoted by $EFF(O_m)$, can be calculated by Equation 3.2. The values obtained using this equation are used to fill in the cells in the last row of Table 3.3 for each option next to “Option Effectiveness”.

$$EFF(O_m) = \sum_{y=1}^Y a_{ym} STR(E_y) \quad (3.2)$$

When the Option Effectiveness has been computed, one can rank the options in a model from most important to least important in descending order, such that the options that have higher effectiveness values are more important than the options with lower effectiveness

values. A tie between options in terms of effectiveness values is possible and indicates that these options have similar importance.

Table 3.3 Tabular form of the Option Effectiveness approach (Alhindi et al., 2018c), © 2018 IEEE

	O_1	O_2	...	O_M	<i>Strength of Equilibrium</i>
E_1	a_{11}	a_{12}	...	a_{1M}	$STR(E_1)$
E_2	a_{21}	a_{22}	...	a_{2M}	$STR(E_2)$
\vdots	\vdots	\vdots		\vdots	\vdots
E_Y	a_{Y1}	a_{Y2}	...	a_{YM}	$STR(E_Y)$
<i>Option Effectiveness</i>	$EFF(O_1)$	$EFF(O_2)$	...	$EFF(O_M)$	

3.3 Summary

The Option Effectiveness approach is developed and designed in this thesis as an expansion to the GMCR methodology. The procedure determines the importance or impact of each option based on its selection within each equilibrium state in the conflict model, as well as the types of solution concepts, or behavior under conflict, that form the equilibria. More specifically, the strength of an equilibrium type from strongest to weakest is Nash, SEQ, SMR, and GMR. Based on this, the effectiveness or impact of a given option is computed according to its presence in each equilibrium state. This permits the options to be ranked according to their importance or effectiveness in resolving the dispute under consideration. The Option Effectiveness procedure enhances a given DM's understanding of the impacts of

the options in the conflict, and in turn allowing the DM to focus his or her efforts in selecting options that will have a larger influence in resolving the conflict.

Chapter 4

Shifting Paradigms in the Global Political and Economic Arena

The achievement of superpower status has been the goal of many countries around the globe and is the underlying reason for the conflict between China and the United States (US) over global trade agreements. The conflict is thoroughly investigated in Chapter 5. However, to reach a sound understanding of the nature of this conflict, one needs to understand the political history of these two nations. This chapter explains the aftermath of World War II and the US path to global dominance, as well as the struggles of China in the mid-1900s and its actions to improve its economy.

4.1 The Emergence of the United States as a Global Superpower

The US began to emerge as a superpower long before World War I (WWI). The main contributing factor was the economic drive and expansion of the US. America's geographical presence played a vital role in its economic expansion. American soil was rich in minerals and oil, and great for agriculture and later for industrial production. This paved the way for international trade and commerce, which caused US ideologies, beliefs, and culture to be transferred across the world (Mead, 2002, p. 103). Consequently, proceeds from trade were used to strengthen US defense, particularly the navy, which was helpful in transporting its produce internationally. Furthermore, this wealth was accompanied with advanced technological innovation, research and development, which led to increased production and enhanced output quality, further improving the economic capabilities of the US (Abramovitz

& David, 1973). As a result, rising US economic prosperity and national security enabled its leaders to undertake crucial local and international projects that were implemented through the use of “soft power”, resulting in US dominance in world politics (Efthymiou, 2013).

The US did not strengthen its military capacities to actively participate in world conflicts, but rather to prevent other nations from challenging the US militarily (McDougall, 1997). Many saw the US as being a patrolling agent that would use its military might only as a force of good. Its leaders used mediation and soft power to further American interests and deter conflicts amongst other nations, reinforcing its leadership and giving the US an edge in international diplomacy (Efthymiou, 2013).

An example of the point made above can be seen in the US reluctance to participate in WWI. It took three years for the US to join in the war, predominantly because Germany’s naval-based warfare threatened US trade with Britain and France, and strained American banks that had loaned substantial funds to Britain (Stevenson, 2004, p. 318; Schulzinger, 2008, p. 63). The US aim in WWI was to bring an end to the war, victory to its allies and peace to the world, and to establish a foundation for the League of Nations to safeguard American interests. The outcome of WWI demonstrated US supremacy, leading to its recognition as a global superpower. Its aid to the Allies, without which victory would have been unachievable, gave it a leading role in international affairs, particularly in European (Stevenson, 2004, p. 319; Efthymiou, 2013).

With WWI coming to an end, most Americans were of the opinion that participating in international affairs would be detrimental to America's economy, and thus the US adopted a policy of isolationism, a national policy that would keep the US from engaging in politically and militarily complicated affairs. The US followed this policy throughout the 1920s up to World War II (WWII). As a result of this policy, America's political relations in Latin America improved tremendously (Weisberger et al., 2018). Despite political tensions in Europe, America persisted in its isolationist policy. In 1935, Congress passed the Neutrality Act, which barred the supply of munitions to belligerent countries, whether they were the target or the attacker. The same course of international policy was also maintained in the Pacific region, where America continued to refrain from intervening in Japan's invasion of China in 1937. Instead, it continued to focus on peace-building and defense, strengthening its navy and establishing security treaties with the other North and South American governments (Weisberger et al., 2018).

However, as the world drew closer to the rise of another world-wide catastrophe after the invasion of Poland in 1939 by Germany, known as WWII, America was compelled to revise its neutrality act, and with the defeat of France in 1940 by Germany, it decided to supply armaments to the Allies, specifically Britain and France, on a cash and carry basis. In fact, the topic of the quantity of arms to be supplied to the Allies became a bone of contention during the US election in 1940, which was won by the incumbent, Franklin Roosevelt. As Roosevelt returned to office, he passed Lend-Lease legislation in March of 1941 which

further guaranteed US aid to the Allies on credit and which was also later extended to the Soviet Union, making the US an undeclared war participant (Weisberger et al., 2018).

Moreover, the situation in the Pacific, in regard to Japan's involvement in the war, made US participation in the war ever more likely. Although the US had always supported China, at the same time it was supplying Japan with commodities such as scrap metal, gas, lubricants etc. that were crucial in Japan's war against China. Thus, in order to support China against Japan, the US loaned funds to China and banned the supply of scrap metal and all other types of commodities to Japan that would prove helpful in producing munitions. From that point in time, US relations with Japan deteriorated, as a series of events unfolded depicting Japan's retaliation. The biggest example of this involved Japan joining hands with Germany and Italy and the subsequent surprise attack at Pearl Harbor which left the US with more than three thousand casualties and confirmed the US belief that participation in the war was unavoidable. Thus, the US formally declared war on Japan, and Germany and Italy responded by declaring war against the US (Weisberger et al., 2018).

Although the US officially declared war when Pearl Harbor was attacked, it was not adequately prepared for it. President Roosevelt along with his advisors had been able to devise military plans, but due to lack of public support, sufficient expenditures had not been allocated to the production of weaponry except for the navy, whose size was inadequate to fight a two-ocean war. Nonetheless, the situation improved later in the war, when more than 15 million people were hired in defense services, and resources were reallocated to

augmenting the production of the defense industry. Consequently, an Office of War Mobilization was founded to oversee the defense industry. The supply of raw materials was redirected towards supporting defense production, and gradually other industries were set up such as for synthetic rubber. Moreover, the Office of Price Administration was also established to monitor inflation levels. Eventually, by 1944, the defense industry flourished and arms production more than doubled the capabilities of all the opposing nations combined. Furthermore, from the technological aspect, breakthroughs were made, and innovative products were developed such as radar, sonar, rockets, proximity fuses, and most importantly the atomic bomb (Weisberger et al., 2018).

Socially conditions improved as well, as unemployment declined drastically, with employment figures reaching 53 million by 1945, leading to a shortage of manpower. The Fair Employment Practices Committee was also founded, abolishing racial discrimination and giving equal rights to everyone to participate in defense services, which further enhanced production. As such, near-zero unemployment led to higher income levels, which ultimately translated into economic prosperity for the country (Weisberger et al., 2018).

US involvement in WWII carved a new role for it in the domain of international affairs, as it led to termination of the isolation policy and brought about the establishment of the United Nations (UN) in 1941 by President Roosevelt and Prime Minister Winston Churchill, which was an extension of the cooperation of the 26 Allied nations during the war. Backed with public support for the UN, planning for the post-war structure of the UN went ahead.

Eventually, on October 24th, 1945, 50 nations collaborated to lay the foundation for a permanent United Nations, pledging the US's commitment to a global organization with sufficient authority to maintain an "everlasting" peace. The UN is headquartered in New York City and is a successor to the former League of Nations, which was established during WWI and later terminated in 1946, displaying a shift of world power from Europe to the United States of America (Weisberger et al., 2018).

Besides the establishment of a united political charter, the UN, President Roosevelt also encouraged economic collaboration through the creation of the two most significant international financial bodies in the world, the World Bank and the International Monetary Fund (IMF), at the Bretton Woods conference, the purpose of which was to eradicate the culture of economic nationalism which placed the interests of one nation above all others (Wan, 2016, p. 60; Weisberger et al., 2018).

The next subsection explains how the US was able to maintain its global supremacy through utilizing the World Bank and the IMF to its political and economic advantage.

4.1.1 The World Bank and the International Monetary Fund

The World Bank is associated with the UN, and provides financial assistance to member countries as well as developing countries by funding projects that are vital to their local economic prosperity. It also aids developing countries with the creation of economic policies and reorganization of their government institutions, and is responsible for setting the global economic agenda. The IMF is also affiliated with the UN and works in collaboration with

the World Bank (Chossudovsky, 2018; What We Do, n.d.). According to the official IMF website, “the primary purpose of IMF is to ensure the stability of the international monetary system—the system of exchange rates and international payments that enables countries (and their citizens) to transact with each other” (About the IMF, n.d., “Why the IMF was created and how it works” para. 2). Both the World Bank and the IMF are headquartered in Washington DC, and are together known as the Bretton Woods Institutions.

The location of the headquarters of the two largest international financial agencies in the world expresses the magnitude of the influence the United States has on their operations. This was one of the issues that the nations participating at the Bretton Woods conference disagreed upon. As noted by Catherine Gwin, “the United States has viewed all multilateral organizations, including the World Bank, as instruments of foreign policy to be used for specific U.S. aims and objectives” (Gwin, 1997, p. 195). The US Treasury desired for the headquarters to be located in the capital, Washington DC, which was close to the US Congress, as opposed to the other participating nations, which favored New York City as the better location due to its future proximity to UN headquarters. Initially, John Maynard Keynes, a renowned British economist, proposed London as a suitable location for the headquarters of World Bank and IMF; however, the US Secretary of the Treasury at the time, Henry Morgenthau, was smart enough to persuade the other foreign delegations present at the conference that locating the headquarters of the new financial institutions close to an already established leading financial center of the world, the City of London, would cause it

to be dominated by the British Empire. Hence, Washington DC was looked upon as the ideal location for the global financial institutions, situated close to the White House (Toussaint, 2014a).

Relatedly, the US Treasury also ensured that the members of the Board of Directors of the World Bank were permanent residents in Washington DC, an idea which was greatly opposed by Keynes, who suggested that this would cause the US government to exercise unnecessary influence over its members. As argued by Gwin,

throughout the history of the International Bank for Reconstruction and Development (the World bank), the United States has been the largest shareholder and the most influential member country. U.S. support for, pressure on, and criticisms of the Bank have been central to its growth and the evolution of its policies, programs, and practices. (1997, p. 195)

Also, Gwin (1997) commented that “the top management of the Bank spends much more time meeting with, consulting, and responding to the United States than it does with any other member country. Although this intense interaction has changed little over the years” (p. 248). Moreover, Toussaint (2014a) argued that the US government has proposed the candidate to be elected as the president of the World Bank, which is a decision always supported by the Board of Directors, since a representative of another member state has never been given consideration by the Board (Toussaint, 2014a).

Furthermore, although reconstruction of the nations that were destroyed by WWII had been the primary motive for why the Bank was created, nonetheless, the US government announced the launch of the Marshall Plan (officially the European Recovery Program) to regulate the lending operations of the World Bank (Toussaint, 2014a). In order to better understand this notion, one must peek further into the events of 1920. At the end of WWI, the Treaty of Versailles was signed at the Paris Peace Conference, which accused Germany of being responsible for the War (MacMillan, 2002).

As compensation for the destruction WWI had caused, Germany became heavily indebted to Belgium, Britain, and France, who were in turn indebted to the United States and thus relied heavily on Germany to pay its debts so they could repay their own debts to the US. This led to the onset of a worldwide economic recession whereby Wall Street crashed in 1929, causing Germany to default on its debts to the Allies and they to in turn default on their US loans, leading to the Great Depression. Therefore, in order to avoid another economic catastrophe after WWII, the US created the Marshall Plan, which was an initiative to offer funds in the form of *grants* and not *loans* to European countries to help rebuild their economies. This initiative would then help the US to maintain the full employment level that was achieved during the war years due to the astronomical growth of its defense industry, and also uphold the level of international trade. As a result, through the World Bank, the US between 1948 and 1951 offered grants worth more than 13 billion US dollars to help reconstruct 17 European economies, which translates to 120 billion US dollars as of today in

approximate terms, upon the condition that the funds be used to purchase US-produced goods as opposed to those of its communist rival, the Soviet Union (Toussaint, 2014b). In fact, the first loan by the World Bank was made to France on the condition from the US that the French Communist Party (FCP) be eliminated from the French government. Soon after the FCP was forced out of the government, a loan of 250 million US dollars was made available, exhibiting the influence US could exercise over the Bank's policies (Toussaint, 2014a).

Since the inception of the World Bank until the present day, US has possessed veto rights at the World Bank and has always taken measures to retain its power. An example of this can be seen in the situation the US was presented with in 1987 when Japan demanded an increase in its voting rights. The US responded by reducing its own voting rights; however, it raised the majority required to exercise influence over the Bank's policies to 85% as opposed to the previously 80%. In doing so, the US was able to preserve its veto rights while meeting the demands of Japan, which placed it ahead of both Germany and Great Britain (Toussaint, 2014a). Currently, US holds 15.98% of the voting power, which still suffices for the purpose of maintaining its veto power (World Bank, 2018).

Another argument that demonstrates the US's attempts to utilize the Bank for its own interests is present in the measures it takes to protect its economy from foreign competition. From the 1970s, the US has been successful in persuading the Bank to avoid loaning funds that would generate competition for US goods and services such as palm oil, sugar, and citrus

fruits, and in 1987 loans to steel manufacturers in both India and Pakistan were greatly curtailed in favor of the US economy (Toussaint, 2014a).

Conclusively, the presence of the World Bank is not only utilized as an instrument of foreign policy by the US, but it also provides favorable financial implications for the US. Since its inception, US contributions to the World Bank are estimated to be 1.85 billion US dollars, whereas the Bank's lending have amounted to 218.21 billion US dollars in total (Toussaint, 2014a; Gwin, 1997, pp. 271-272). As further estimated by Gwin (1997), between the period 1947 to 1992, the income of the Bank raised through the issuance of World Bank bonds to US citizens amounted to 20.2 billion US dollars while the outlay within the US amounted to 11 billion US dollars (pp. 271-272). This clearly demonstrates that US firms in particular have largely benefitted from these loans (Toussaint, 2014a).

In recent years the US had been working on the Trans Pacific Partnership (TPP) Agreement, a trade agreement to stimulate trade by reducing tariffs among participating countries (Ablow, 2016). Negotiations regarding the TPP started under the Obama administration, but US involvement in the TPP came to an end when President Donald Trump withdrew the US from it in 2017 (Evans, 2017). The US withdrawal from the TPP caused a vacuum on the global economic stage and might have paved the way for China to succeed as the next global economic leader through China's own international trading agreements, which will be covered in the next section of this chapter (Wong, 2017; Sink, Olorunnipa, & Curran, 2017).

For the last 100 years, the US has been able to maintain its predominance on the global stage, backed by the influence it is capable of exerting through the World Bank and the IMF as well as its military might. However, that predominance is being challenged by the economic, technological, and military emergence of China, which might overshadow the global supremacy of the US in the future.

4.2 China's Rise and Its Emergence as a World Superpower in the 21st Century

For many centuries prior to the 18th, China was recognized as the biggest economic superpower in the world. Hence, it can be considered that China is only re-emerging, in the 21st century, to its rightful place on the global stage. For instance, in 1078 China produced what is estimated to be 125,000 tons of steel compared to Britain's production, in year 1788, of 76,000 tons. China was also leading technological innovation in the textile industry seven centuries prior to Britain's textile revolution in the 18th century, and China was ahead of many nations in the trading sector with its advanced navigation systems, consisting of trade networks reaching Europe, Africa, South Asia, and the Middle East, which helped in the transportation of its innovative goods such as paper, weapons, book printing, and tools, making it a manufacturing superpower. As well, China's agricultural industry was second to none until the 18th century. China also controlled a fleet of commercial ships considered to be the world's largest at the time, able to carry 3,000 tons of goods in 1588, whereas Britain's ships could only displace 600 tons by the end of the 18th century. The Chinese at one time possessed around 130,000 private transport ships, and China matched Great Britain's per

capita income due its robust banking industry and the high returns from the agricultural sector (Hobson, 2004, pp. 51-73). China's esteemed economic status was unchallenged until the end of the 19th century (Petras, 2012).

China suffered the most from British and Western colonization of the East, which was of a militaristic nature. These colonizing nations followed a scheme of non-equal economic relations, and dominated opposition by military force whereas China's prosperity was achieved by its belief in reciprocal benefits in its trading relations (Gott, 2011). However, failing to dominate the Chinese market by economic competition, Britain used its military power to force its goods on China and enforcing non-reciprocal deals to lower the tariffs on its goods. This resulted in British opium, produced in India, to overflow in China, despite Chinese law forbidding imports of narcotics. Consequently, the Chinese suffered from the Opium Wars with the British and millions hence being enslaved by opium. As the Chinese rulers failed to realize the military strength of the colonizing countries, China's esteemed economic status met its end. As for the militaristic aspect, the British secured their dominance over China through the enormous militarization of its economy, which was dependent on resources apprehended from its massive colonies (Hobson, 2004). The 20th century was devastating for China as not only had it lost its global supremacy to the West, but most of its population was suffering from poverty and destitution. Furthermore, its main ports were in the possession of Western countries, whereas the countryside was ruled by cruel and immoral warlords (Petras, 2012).

The beginning of China's remarkable new rise can be traced back to the year 1945, when China achieved its independence following the defeat of Japan by the US at the end of World War II. At the time, the leadership of China was mainly divided between Mao Zedong's Communist Party and the Kuomintang regime of Chiang Kai-shek; this situation elevated concerns over a new civil war (Bernstein, 2015; Kamrany & Jiang, 2015). A civil war broke out in 1946 between the Communists and the Kuomintang, in which Mao and his communist party emerged victorious in 1949. On October 1st, 1949 the People's Republic of China was founded by Mao marking the beginning of the one-party government in China (BBC, n.d.; Yu, 2015). The Communist Party's regime worked on eradicating countryside warlords and gangster rule, stopping the advantages of Western imperialists, and chasing down the rich owners of blacklisted businesses such as brothels and drug- and people-trafficking. The Chinese revolution under the Communist government was crucial in forging the current state of China (Petras, 2012). The economic reforms were initiated by the new leaders under the "Great Leap Forward" program aimed towards improving industrial and agricultural productivity through mobilizing labour in order to uplift the devastated Chinese economy. This resulted in a huge decline leading to massive casualties, and in turn, the program was abandoned (BBC, n.d.).

The start of 1980 marked the beginning of a new era where communist China shifted its economic policy towards a more capitalism-oriented one. In the coming decades, China would open its market to foreign investment and privatize many state-owned industries. In

addition, the Chinese leadership embraced the idea of transferring technical knowledge by providing a low-cost workforce for overseas firms. The leniency towards a capitalist economic vision allowed China's economy to prosper rapidly. The continued growth of China's manufacturing industry was a product of public investment, technological advancement, and a firmly regulated domestic market in which both local and foreign investment would be profiting. The Chinese government's bold export policy and the liberalization of the Chinese market made China one of the major exporters in the world (Petras, 2012).

The importance of the US was evident to China, and in the 1980s, it became the main destination for its exports (Jacques, 2012, p. 179). In 2007, China had an unprecedented trade surplus resulting in China becoming one of the biggest creditors in the world (Hirst, 2015; Petras, 2012). In order to continue its economic dominance, China required procurement of raw materials in huge quantities, which resulted in China investing overseas and partnering in international trade agreements focusing on nations in Latin America and Africa. China has maintained its policy of not interfering in the internal affairs of its trading partners, contrary to the policy followed by its rival, the US (Petras, 2012). Furthermore, China has started to participate in international financial organizations. For instance, it joined the IMF and the World Bank in 1980 (Wan, 2016, p. 62) and the Asian Development Bank (ADB) in 1986 (Wan, 2016, p. 68). However, with China being a communist country and so viewed as suspicious by the US, delayed its participation in the World Trade Organization

(WTO) by almost 15 years, and after finalizing the most detailed agreements of any country, China was able to join the WTO (Jacques, 2012, p. 178).

In the last three decades, China's gross domestic product growth rate has averaged about 9% annually (Husna, 2018). Meanwhile, it continues to invest in energy and mineral sectors throughout Africa. China has also been replacing US- and European-led international financial institutions such as the IMF and the World Bank as the principle lender (Petras, 2012). As a result, Chinese influence in the last decade has grown to be tangible and real rather than a set of statistics and speculations (Jacques, 2012, p. 409).

4.2.1 Chinese Global Economic Initiatives

In 2013, China formally initiated the idea of establishing an international bank that would finance infrastructure projects around Asia and the world, named the Asian Infrastructure Investment Bank, involving 57 countries in which China was the largest shareholder (About AIIB Overview - AIIB, n.d.; Wan, 2016, pp. 44, 75). The AIIB along with China's ever-growing economic power is considered a direct challenge to the US and Japan, rivaling the World Bank, the IMF, and the ADB, and increasing Chinese influence in Asia and the World (Wan, 2016, p. 11). Some consider that the idea of establishing the AIIB was driven by the grand Chinese plan of the Belt and Road (B&R), formally known as the One Belt One Road (OBOR) initiative (Wan, 2016, pp. 51-52). Moreover, China's voting share in the AIIB is around 26%, permitting it to exercise veto rights in the bank's decisions, as 75% of total voting shares are needed to pass important actions (Wan, 2016, p. 50). Moreover, China's

veto rights could be revoked in the case that more countries, such as the US and Japan, joined the AIIB (Mie, 2016; Wan, 2016, p. 50). The bank's primary focus is to finance projects launched by the B&R (Mitrovic, 2018).

The B&R initiative, launched in 2013, involves more than 65 countries and a collective population of 4.4 billion people. Its objective is to develop connectivity in five main areas: people, currency, trade, infrastructure, and policy, with priority assigned to the development of transportation networks including seaports, roads, and railways (Mitrovic, 2018). Building infrastructure for connectivity of energy is another area of focus for the Belt and Road initiative (Mitrovic, 2018). The initiative aims to connect Southeast Asia with Western Europe through Chinese infrastructure, which will supposedly stimulate economic growth across China, Asia, and the globe (Cheng, 2018; Mitrovic, 2018). The term "Belt" refers to the Silk Road Economic Belt, similar to the ancient silk road, stretching all over Eurasia (Cheng, 2018). The "Road" is the 21st-century Maritime Silk Road intended to connect China to the Mediterranean Sea (Cheng, 2018). It is estimated that China is willing to invest 150 billion US dollars annually into the B&R initiative (Phillips, 2017). In fact, analysts are indicating that this initiative has the capability to overshadow the US Marshall Plan post-World War II ("China's One," 2016).

Recently, China has also been engaged in the launch of the Regional Comprehensive Economic Partnership (RCEP) Agreement, which involves US allies such as South Korea and Japan and is intended to be the world's largest free-trade agreement (Brinkley, 2017).

The agreement focuses on free trade and lower tariffs among participating countries (Regional Comprehensive Economic Partnership (RCEP), 2016; Regional Comprehensive Economic Partnership, n.d.; Mathieson, 2017).

Backed by the highest foreign currency reserves in the world, valued in excess of 3.1 trillion US dollars (Picardo, 2018; IMF Data, n.d.), the AIIB, B&R, and the RCEP agreements will enable China's vision to emerge as the strongest economic power in the world, surpassing the US, is clear, and its objectives to achieve that are in motion. One can only wait and see how the future will unfold and whether the US will be able to retain its supremacy over China.

4.3 Summary

The US has emerged as an economic and military global superpower since after WWII. It established global financial institutions such as the IMF and the World Bank to demonstrate its global economic influence. However, China's unprecedented economic rise through its economic reforms that started in the 1980s allowed it to challenge the US supremacy. It launched its own led financial institution, the AIIB, and a unique global initiative the B&R connecting Southeast Asia with Western Europe to increase global trade through massive infrastructure investment. The Chinese are also working on implementing the RCEP trade agreement to increase its economic dominance. The US withdrawal from the TPP at the start of 2017 may have paved the way for China to act as a global economic leader. However, it

is yet to be seen how the future will be revealed and whether China will be able to overshadow US dominance.

Chapter 5

The Conflict Between China and the US over Global Trade Agreements

In recent years, China has surprised the world with its economic and military rise. This rise has put the United States (US) status as the world's strongest economic superpower in jeopardy. China is clearly in line to at least share this status with the US, if not claiming solely for itself (Ahmed, 2011). It all started when China announced an initiative to launch a financial institution named the Asian Infrastructure Investment Bank (AIIB) along with its complementary initiative the Belt and Road (B&R), which would rival the US-influenced World Bank and the Asian Development Bank (ADB). The Regional Comprehensive Economic Partnership (RCEP) is another agreement that China is working on in parallel, which is expected to be the world's largest free trade agreement (Brinkley, 2017). It involves 16 countries including China and Japan (Regional Comprehensive Economic Partnership, n.d.). Interesting facts about China's continued rise include China becoming the world's second-largest economy in 2010 just behind the US, and China becoming the biggest US creditor in recent years. As for the military aspect, China's military spending reached more than 45 billion dollars in 2007 ("Timeline: U.S. Relations," n.d.). However, the US had plans of its own such as the Trans Pacific Partnership (TPP) Agreement, a trade agreement focusing on increasing trade by lowering tariffs among participating countries. Negotiations regarding the TPP started under the Obama administration, but US involvement in the TPP came to an end when President Donald Trump withdrew the US from it in 2017. The trade war between

China and the US was ignited when the Trump administration put forward an act to enforce tariffs, estimated to be in the region of 60 billion US dollars, on Chinese imports (Breuninger & Tausche, 2018), whereas China countered the act by threatening to impose tariffs on US imports (Thomas & Wiseman, 2018).

The trade dispute between China and the US is of great importance, and a thorough investigation of this conflict would allow a better understanding of global politics and international economics. The conflict is studied using the Graph Model for Conflict Resolution (GMCR) methodology to gain critical understanding and clarity about the possible resolutions of this dispute. Examination of the AIIB, TPP, and RCEP initiatives is the main focus of the analysis, as both China and the US are heavily involved in dialogue with each other regarding them, whereas the B&R initiative is removed from the conflict model since it does not involve the US.

The investigation of this conflict uses the idea of the Option Effectiveness approach as an extension to the GMCR methodology, which was explained in Chapter 3. The approach is applied to this conflict as means of evaluating the novel method. As mentioned earlier, the Option Effectiveness approach allows the examination of options, which allows DMs to rank these options according to their importance in contributing to the resolutions predicted by GMCR. This would, ultimately, permit the DMs to make more informed strategic decisions.

The background of the trading conflict between China and the US is discussed in Section 5.2, while the methodology followed in the study is explained in Section 5.3. The modeling

and analyses for the three phases of the conflict are presented in Sections 5.4, 5.5, and 5.6. The application of the Option Effectiveness approach on the three phases of the conflict is shown in Section 5.7, and overall strategic insights are then revealed in Section 5.8.

This chapter of the thesis includes contents from published and unpublished manuscripts “The Conflict Over the Asian Infrastructure Investment Bank Involving China, USA, and Japan” (Alhindi et al., 2017b) © 2017 IEEE, “Option Effectiveness in Conflict Resolution” (Alhindi et al., 2018c) © 2018 IEEE and “The Conflict over Global Trade Agreements Between China and the United States” (Alhindi et al., 2018b).

5.1 Conflict Background

The expanding economic and military strength of China have established it as a rising world superpower. China became the biggest US creditor in September 2008, indicating that China is the largest US debt-holder at around 600 billion US dollars (“Timeline: U.S. Relations,” n.d.). Furthermore, China became the second-ranked economy of the world in 2010, valued at 1.33 trillion US dollars (“Timeline: U.S. Relations,” n.d.). In fact, Mr. Jim O'Neill, the head of Goldman Sachs Asset Management, expects China to surpass the US as the largest economy in the world by 2027 (Ahmed, 2011). In parallel to its economic growth, China also increased its military expenditure by 18% back in 2007, to reach overall spending of around 45 billion US dollars (“Timeline: U.S. Relations,” n.d.). China is undoubtedly a highly influential nation in East Asia, where it dominates economically, and it is extending

its control over the South China Sea. When its economy surpasses that of the US and its military strength further increases, China will clearly be established as a global superpower.

The trade conflict between the US and China is considered as a long-term and time-evolving conflict in this research (Matbouli, Kilgour, & Hipel, 2015), and is divided into three phases. The first phase is when China and its partners establish the AIIB and the US and Japan apply counter-moves. The second part is when the US considers launching the TPP and offers terms to China over the AIIB. The third phase comes after US President Trump entered the Oval Office in early 2017, followed by his withdrawal of the US from the TPP and China's commitment to launching the RCEP. In the second phase, a hypergame model is used to capture misperceptions by both DMs: China, and the US and Japan.

5.1.1 Implementation of AIIB prior to US Terms

The proposal to establish the AIIB was officially made by China in October 2013. It was widely acknowledged and encouraged both regionally and globally (Wong, 2016). However, the US has strongly opposed the idea as it fears that its Chinese counterpart would use the bank as means to set its own economic schemes and agendas globally (Perlez, 2015). Therefore, the US and Japan lobbied their allies against joining the AIIB (Perlez, 2015). However, this lobbying was not effective, as many of their allies, including the United Kingdom, France, Germany, and Italy, joined the AIIB, which was officially launched in October 2014 (Goh, 2014; Huang, 2015; "France, Germany, Italy to," 2015).

5.1.2 Introduction of TPP and US Terms for China over the AIIB

China is considered one of the world's fastest-emerging superpowers, especially after the establishment of the AIIB, which allowed it increased influence in the Asia-Pacific region (Perlez, 2015). This rapid influence gain for China is a major concern for the US and Japan (Perlez, 2015). Hence, the US, led by Obama at the time, and its allies in the region wanted to bind their economic relationships further. The TPP, a regional trade agreement, emerged as the binding instrument (Ablow, 2016). The TPP agreement involves open trade and low tariffs among the twelve contributing nations (Ablow, 2016). The TPP was perceived to be of major significance by the Obama administration to help the US economy and gain further influence over the Asia-Pacific region (Ablow, 2016). Also, it was considered as a key factor in reducing the ever-growing Chinese influence over the region (Ablow, 2016). However, some experts believe that the TPP agreement may actually prove beneficial to China, as it will improve economic prospects in the region (Wang, 2016).

The AIIB is interpreted by the US, Japan, and other nations as being a direct competitor to the world's current leading organizations and banks, such as the International Monetary Fund (IMF) (About the IMF, n.d.), the World Bank (What We Do, n.d.), and the ADB (Who We Are, n.d.). The US and Japan are major shareholders and DMs in these organizations (Asian Development Bank, 2015; "IMF Members' Quotas," 2018; World Bank Group, 2015), and hence, having another competitor like the AIIB would adversely affect the influence of the US and Japan through these organizations.

According to The Financial Times, the US in 2015 declared a truce in its campaign to block the Chinese-led AIIB (as cited in Donnan, 2015). However, while the US maintained its decision to not join the AIIB, it claimed that it had received assurances from China that China would address US doubts regarding the AIIB. These assurances included that China would increase its grants and investments to the World Bank. China also committed to the AIIB functioning under proper environmental and governance standards (Donnan, 2015).

The membership of the US and Japan in the AIIB is, in fact, a threat to China (Mie, 2016). Kawai, from University of Tokyo, expects that the US and Japan joining the AIIB may block China from its veto rights in the organization since the duo would have around a 20% voting share (Mie, 2016). Instead, to impact decisions in the organization, China would have to rely on its alliance with Russia, which controls about 5% of the voting share (Mie, 2016).

5.1.3 Post-Obama Era and Implementation of RCEP

In January 2017, after winning the US presidential election in November 2016, the Trump administration decided to withdraw from the TPP by signing an Executive Order (Evans, 2017). This order created a void and made it possible for another trading entity to emerge and to fill the leadership role in global trade (Sink et al., 2017). In fact, this trading entity can be China since it has the capability of filling the void caused by the US withdrawal from the TPP (Sink et al., 2017).

The US withdrawal from the TPP allowed China to expand its influence in the Asia-Pacific region (Wong, 2017), which it is actively doing. As stated by Zhang Jun, an economic affairs

official at the Chinese foreign ministry, “If China has taken up a leadership role, it is because the front-runners have stepped back, leaving that place to China” (as cited in Sink et al., 2017). The implementation of the RCEP would undoubtedly strengthen the Chinese leadership role. Other countries that were participating in the TPP may have no other choice but to join the RCEP in order to benefit from other trade agreements after the collapse of the TPP (Brinkley, 2017).

The RCEP is a trade agreement that involves sixteen nations including China and Japan (Regional Comprehensive Economic Partnership (RCEP), 2016; Regional Comprehensive Economic Partnership, n.d.). This agreement excludes the US because the US was promoting its own trade agenda, the TPP, which collapsed under the Trump administration, as just mentioned.

China has also launched the Belt and Road (B&R) initiative, an ambitious program running parallel to the RCEP (Jin, 2017). The Belt and Road initiative focuses on infrastructure investments in massive transportation systems linking China with other nations by roads, railways, airports, and sea navigation, as well as building economic ties among the participating countries by encouraging market integration (Jin, 2017). The Belt and Road initiative will allow further Chinese dominance on a global scale.

5.2 Methodology

The formal strategic investigation of the conflicts arising over trading agreements in the Asia-Pacific region is divided into three key periods of time. The first involves the establishment

of the AIIB prior to the announcement of the US terms. The second is concerned with the inclusion of the US stipulations in the AIIB and the founding of the TPP as a counter-move by the US and Japan. The possibility of misperceptions occurring at this time is also considered in what is called a hypergame analysis. Within the third time period, the evolution of the conflict into the era of the Trump administration in early 2017 is studied by removing the launch of the TPP by the US and including the implementation of the RCEP by China.

For a given point in time, each phase of the conflict is separately modeled and analyzed using GMCR (Fang et al., 1993; Kilgour & Hipel, 2005; Kilgour & Hipel, 2010; Xu et al., 2018). In the modeling stage, what has to be determined first are the DMs holding real decision-making power in the conflict, plus each DM's courses of action or options, representing their power. The second step is to establish the relative state rankings of each DM in terms of feasible states or scenarios which could arise based on the DMs decisions about which option to select. A well-established approach for ranking these states is the option prioritization method, which satisfies all the rules of first-order logic (Fang et al., 2003a, 2003b). By knowing the possible moves and counter-moves that each DM could make in a conflict, one can carry out what is called stability analysis for a given state using a range of solution concepts, which include Nash (Nash, 1950; Nash, 1951), SEQ (Fraser & Hipel, 1979, 1984), GMR (Howard, 1971), and SMR (Howard, 1971) stability, which are explained thoroughly in Chapter 2 of this thesis. Stability analysis of a conflict allows a DM to understand whether it is beneficial for the DM to move to a more preferred situation.

Following the novel approach explained in Chapter 3, the strength of the equilibria and Option Effectiveness can be calculated after the stability analysis of a conflict, which permits ranking of the options with respect to their contributions towards the equilibrium states of the model, thereby allowing the DMs a better understanding of the options and their importance.

5.3 Implementation of the Asian Infrastructure Investment Bank prior to United States Terms

As mentioned earlier, the conflict is divided into three phases in time. The first phase starts when China establishes the AIIB, preceding the time when the US proposes its terms concerning the AIIB. The stability analysis is carried out by building the conflict model for the first phase. The model is based on several key factors that have to be determined and identified. First, a point in time is considered. Then, the DMs involved and the options they control are identified, the DMs' relative preferences are determined, and the reversible and irreversible moves are clarified. This section thoroughly explains the model construction in the first phase of the conflict followed by the stability analysis.

5.3.1 Conflict Model for First Phase

5.3.1.1 Point in Time

The conflict started in October 2013 when China proposed the launch of the AIIB. However, the model constructed for the first time period considers February 2014 as the point in time at which to study the conflict. By this date, the US counter-move to oppose the AIIB had

been already revealed and tension over it was growing between China on the one side, and the US and Japan on the other.

5.3.1.2 Decision-Makers

China and the US and Japan are the key DMs in the conflict. Moreover, the background of the conflict reveals that the US and Japan have a mutual interest in the conflict and possess similar options. Hence, the pair is considered as a single DM. The conflict model, therefore, only considers two main DMs: China and the US. Accordingly, the other DMs who may have played a vital role in establishing the AIIB in terms of joining the AIIB and contributing to its capital even against the will of the US and Japan, like France, Germany, Italy, and the United Kingdom (“France, Germany, Italy to,” 2015), have been excluded from the model.

5.3.1.3 Decision-Makers’ Options

The options at this point in time are summarized in Table 5.1, which explains the options that each DM controls in the conflict.

Table 5.1 First phase DMs’ options

DM	#	Options	Explanation
China	1	Establish the AIIB	Formation of the AIIB by China and participating members while functioning under the best environmental and governance standards.
	2	Join the AIIB	The participation of the US and Japan in the AIIB could result in nullifying the veto rights of China in the organization.
US	3	Oppose the AIIB	The US and Japan will lobby and influence their allies against joining the AIIB.

5.3.1.4 Option Form

The conflict at this stage consists of three options, for which China controls one option and the US two, as listed in Table 5.2. Each option can either be chosen or not selected, and therefore the conflict has $2^3 = 8$ mathematically possible scenarios or states. Scenarios or states which cannot occur in the real world are referred to as infeasible states and should be removed from the model. Often, infeasibilities can be expressed in terms of options, which, as explained later, are used to define states. Some sets of options are mutually exclusive so that at most only one from a set can be selected. Other infeasibilities can be expressed using what is called option interdependencies. The infeasibilities of the first phase of the AIIB conflict will now be explained.

a. The United States:

- Option 2 and Option 3 are mutually exclusive, as the US cannot join the AIIB while it opposes the AIIB at the same time.

b. China – The United States:

- Joining the AIIB or opposing it for the US is dependent on China establishing the AIIB.

After removing the infeasible situations expressed in terms of options, four feasible states remain in the model, as indicated by the columns containing Ys and Ns given in Table 5.2. The option form, illustrated in this table, is used to represent these states within the GMCR model. Each state in the model constitutes a unique set of selected and unselected options.

A chosen option is assigned the entry ‘Y’ in Table 5.2 and an unselected option is assigned the entry ‘N’. For example, State 4 in Table 5.2 can be represented by the state written horizontally in text as (Y N Y), in which China decides to establish the AIIB (as indicated by the Y opposite Option 1), the US does not join the AIIB (as shown by the N opposite Option 2) and the US opposes the AIIB (as expressed by the Y against Option 3). The four states are numbered in the top row of Table 5.2 simply for the convenience of easily referring to them. Hence, the numbers are labels and have no quantitative meaning. The ranking of states shown in the lower part of the table orders every state from most preferred on the left to least preferred to the right for each DM in terms of their preferences, which are based on option prioritization statements described in the next sub-section.

Table 5.2 First phase option form

DM	#	States (Ordered)	1	2	3	4
China	1	Establish the AIIB	N	Y	Y	Y
	2	Join the AIIB	N	N	Y	N
US	3	Oppose the AIIB	N	N	N	Y

5.3.1.5 Decision-Makers’ Preferences:

The goal for any rational DM in a conflict is to reach the most preferred scenario or state by appropriately exercising the options it controls. Often a DM may prioritize one option over another in terms of choosing it or not selecting it over the duration of the conflict. In other situations, a DM’s selection of options in terms of its importance may be conditional upon

what another DM does. Assuming ordinal preferences, whereby states are ranked from most to least preferred with ties allowed, a simple algorithm takes the hierarchical preference statements and converts them to a ranking of states or preference rankings for a given DM. This approach is referred to as Option Prioritization (Fang et al., 2003a, 2003b). Often, after obtaining the initial states' ranking from the option prioritization approach, a manual sorting of the states is required to reach the final states' ranking order. The manual sorting allows the analyst to reach a ranking of states which would be similar to reality. However, manual sorting was not required for the first phase.

The ranking of states for each DM allows the determination of the UIs in the conflict from each state with respect to that DM. "UI" is a term explicitly used for referring to a move that will improve the DM's situation by shifting the conflict to a more preferred state than the current one for the DM that controls the UI. However, "UM" is a general term to express all the available moves from a given state. Therefore, all the UIs fall under the UMs, but the opposite is not true.

The option prioritization approach shown in Table 5.3 prioritizes each option based on preference statements. These statements are prioritized in Table 5.3 from most prioritized at the top to least prioritized at the bottom. A preference statement may include more than one option in which these options are conditionally prioritized. Table 5.3 shows the option prioritization for this conflict. The third column shows the short form of the preference statement as entered in GMCR II software. A positive number means that the option is

selected, while a negative number reflects that the option is unselected. For example, the short form of Statement #1 for China, which has Option 1 as selected and Options 2 and 3 as not selected, can be written as 1 & -2 & -3. The preference statement for each DM is shown in the fourth column of the table, with their priority rankings shown in the third column. For convenience, each statement has been numbered in the second column of the table.

Table 5.3 First phase option prioritization for each DM

DM	#	Short form of the preference statements	Preference Statements	Comments
China	1	1 & -2 & -3	Establishing the AIIB while the US does not exercise any counter-move	China will gain influence through the establishment of the AIIB, although this influence can be affected negatively if the US joins or opposes the AIIB.
	2	3 IF 1	The US to oppose the AIIB	China prefers that the US keeps opposing the AIIB rather than joining the AIIB.
	3	2 IF 1	The US and Japan to join the AIIB	This option might nullify the veto rights of China, and that is why it is the least prioritized option.
US	4	-1	China to remain at status quo	The US prefers that China does not take any action.
	5	3 IF 1	Oppose the AIIB if China establishes the AIIB	This action may result in fewer participants in the AIIB, reducing Chinese influence in the region.
	6	2 IF 1	Join the AIIB if China implements the AIIB	China's veto rights in the AIIB could be revoked, given that the US and Japan join the AIIB together.

Table 5.4 First phase preference ranking of states for China

DM	#	Options	Strategies			
China	1	Establish the AIIB	Y	Y	Y	N
	2	Join the AIIB	N	N	Y	N
US	3	Oppose the AIIB	N	Y	N	N
	State Ranking China		2	4	3	1

Table 5.5 First phase preference ranking of states for the US

DM	#	Options	Strategies			
China	1	Establish the AIIB	N	Y	Y	Y
	2	Join the AIIB	N	N	Y	N
US	3	Oppose the AIIB	N	Y	N	N
	State Ranking US		1	4	3	2

The state rankings shown in Tables 5.4 and 5.5 for China and the US respectively are the final product of the option prioritization method. For example, State 2 in Table 5.4 is the most preferred for China since it is well aligned with Statement 1 in Table 5.5, while State 1 is considered the least preferred because maintaining the status quo for the Chinese contradicts the priorities set by Statements 1, 2, and 3.

5.3.1.6 *Reversible and Irreversible Moves:*

The identification of reversible and irreversible moves, once an option is selected, is essential in the stability analysis, since the irreversible moves cancel out the UI or UM for any state

that can be achieved by withdrawing the selection of an option. The following assumptions are made for the DMs with respect to option reversals if they are selected.

- China: The move to select Option 1 (i.e., establishing the AIIB) is irreversible because withdrawal from a large organization, having almost US 100 billion dollars in capital, is assumed to be difficult and tends to require complicated procedures.
- The US:
 - The decision to implement Option 2 (joining the AIIB) is irreversible, as capital withdrawal from a large and controlled organization such as the AIIB is a difficult process since it may require voting from members.
 - The action of selecting Option 3 (opposing China over AIIB) is reversible, which is an independent move. The US may stop opposing the AIIB if its conditions are met, which will be further explained in later phases of the conflict.

5.3.2 Stability Analysis of the First Phase

A rational DM will look to improve his or her position in a conflict. This can be done through option selections or counter-moves. For instance, if the conflict is currently in status quo, which is State 1 in Table 5.2, China would be tempted to improve its position through a UI to State 2 by establishing the AIIB. As such, the conflict will be in a temporary situation at State 2, at which the US can sanction China's UI via its own UIs through either selecting Option 2 or 3, which will shift the conflict to either State 3 (reached by opposing the AIIB) or State 4 (reached by joining the AIIB). However, it is most likely that the US will choose

State 4 over State 3 since State 4 is more preferred than State 3. States 3 or 4 are the likeliest resolution of the conflict at this stage since China has no way to escape these states to a more preferred state as it does not have the means to do so. Another thing to note is that China prefers State 3 and 4 more than State 1 for any given case, which makes it very likely that China will make the move to select Option 1, establishing the AIIB. Similarly, the GMCR method can be used as a formal approach to study the conflict in a comparable manner. The GMCR methodology uses the Nash, SEQ, GMR, and SMR solution concepts to determine the possible resolutions of the conflict. These solution concepts conduct a thorough analysis of the model with respect to the UIs and the UMs for every state under each DM. Tables 5.6 and 5.7 show the individual stability analyses for China and the US respectively, and Table 5.8 shows the equilibrium states obtained through the analyses using the GMCR approach. Table 5.8 reveals that States 3 and 4 are strong equilibrium states, since they are Nash, SEQ, GMR, and SMR equilibria. Therefore, the conflict may end up in one of these states. Table 5.8 also shows that State 2 is Nash stable for China; therefore, China cannot take any UI to reach a more preferred state, while the US has a UI to States 3 and 4, which are considered the equilibrium states for the conflict.

Section 5.2 reveals that ever since China proposed and then implemented the AIIB, the US has opposed and lobbied against it, which represents State 4 in the model. Moreover, if the move to join the AIIB is reversible for the US and Japan, then State 4 is the only equilibrium predicted by the analysis.

Table 5.6 First phase individual stability analysis with respect to China

DM	#	States (Ordered)	1	2	3	4
China	1	Establish the AIIB	N	Y	Y	Y
US	2	Join the AIIB	N	N	Y	N
	3	Oppose the AIIB	N	N	N	Y
Individual Stability		Nash	-	✓	✓	✓
		SEQ	-	✓	✓	✓
		GMR	-	✓	✓	✓
		SMR	-	✓	✓	✓

Table 5.7 First phase individual stability analysis with respect to the US

DM	#	States (Ordered)	1	2	3	4
China	1	Establish the AIIB	N	Y	Y	Y
US	2	Join the AIIB	N	N	Y	N
	3	Oppose the AIIB	N	N	N	Y
Individual Stability		Nash	✓	-	✓	✓
		SEQ	✓	-	✓	✓
		GMR	✓	-	✓	✓
		SMR	✓	-	✓	✓

Table 5.8 First phase stability analysis

DM	#	States (Ordered)	1	2	3	4
China	1	Establish the AIIB	N	Y	Y	Y
US	2	Join the AIIB	N	N	Y	N
	3	Oppose the AIIB	N	N	N	Y
State Ranking		China	2	4	3	1
		US	1	4	3	2
Equilibria		Nash	-	-	✓	✓
		SEQ	-	-	✓	✓
		GMR	-	-	✓	✓
		SMR	-	-	✓	✓

5.4 Introduction of the Trans Pacific Partnership agreement and the United States Terms for the Asian Infrastructure Investment Bank

The conflict between China and the US over global trade agreements was categorized into three phases. This section carries out a thorough study of the second phase in the conflict where three new options in total are introduced in the GMCR model. The US has new options in terms of proposing the terms for China over the AIIB and the launch of the TPP agreement, while China is only limited to either accepting or rejecting the US terms over the AIIB. The model in this phase is constructed and analyzed based on the methods mentioned and used in the first phase. A hypergame analysis (Aljefri, Fang, & Hipel, 2014; Aljefri, Bashar, Fang, & Hipel, 2017), which allows misperceptions, is applied in the second phase with regard to

the implementation of the TPP, since there are claims that the DMs are misperceiving the effect of the TPP.

5.4.1 Model of Second Phase

5.4.1.1 Point in Time:

By February 2016 the information about the launch of the TPP agreement was revealed and the US terms for China over the AIIB were publicized. Therefore, the point in time of the second phase of the conflict is considered as February 2016.

5.4.1.2 Decision-Makers:

The DMs from the first phase of the conflict, i.e., China and the US, are carried into the second phase, since the presented study is only concerned with the US and China. Although there might be other DMs who may play a role in the conflict, for the sake of simplicity they are not considered at this point.

5.4.1.3 Decision-Makers' Options:

The second phase of the conflict introduces a new option for China, which is accepting the US terms over the AIIB, while two more options are introduced for the US, which are launching the AIIB and proposing US terms for China over the AIIB. Table 5.9 lists all the options that each DM controls along with the explanation of each option.

Table 5.9 DMs' options (Alhindi et al., 2017b), © 2017 IEEE

DM	# Options	Explanation
China	1 Establish the AIIB	Refer to Table 5.1
	2 Accept US terms over the AIIB	The terms include increased contribution to the World Bank and governance of the AIIB to the highest standards
US	3 Join the AIIB	Refer to Table 5.1
	4 Request China to accept the terms	The terms as mentioned in Option 2
	5 Oppose the AIIB	Refer to Table 5.1
	6 Launch the TPP	Establishment of the TPP by the US and the participating nations

5.4.1.4 Option Form of the Standard Model:

The option form is used again for presenting the feasible states of the conflict at this stage, which are shown in Table 5.12. The states constitute the selected and unselected options, where 'Y' is assigned for chosen options and 'N' is assigned for unchosen options. Given that the conflict has 6 options at this stage, then there are $2^6 = 64$ mathematically possible states in the conflict. Table 5.12 lists the remaining 18 states (feasible states) after the removal of the infeasible states from the model. For identifying the infeasible states in the second state of the conflict, the following is assumed for each DM.

- China: China accepting the US terms over the AIIB, which is Option 2, is dependent on establishing the AIIB.
- The United States: Option 3 and Option 5 are mutually exclusive. It is not possible for the US to join the AIIB while they keep opposing it.

- China - The United States:
 - Options 3, 4, and 5 (Joining the AIIB, Requesting China to accept the US terms over AIIB, and Opposing the AIIB and lobbying allies against joining it) are dependent on the formation of the AIIB by China.
 - China can only accept the US terms if the US offers them.
 - The US will not further oppose the AIIB if China accepts the terms.

The top row of Table 5.12 orders the states of the conflict from 1 to 18. The lower part shows the states' preference rankings, which ranks the states from most preferred on the left to least preferred on the right for each DM. These rankings are obtained through the use of the option prioritization method.

5.4.1.5 Decision-Makers' Preferences:

The option prioritization method, shown in Table 5.10 for China and Table 5.11 for the US, is used for establishing the states' preference rankings for each DM, which was explained earlier. However, manual sorting of the initial states' rankings was required for it to be well-aligned with reality. Tables 5.10 and 5.11 list the preference statement used to build the preference ranking for each DM respectively. The lower part of Table 5.12 shows the preference ranking for each DM involved in the conflict from most preferred to the left to least preferred to the right. The states shown in the same bracket in Table 5.12 are equally preferred. For example, China's state preference ranking is as follows: 2, 4 > 11 > 13 > 5 > 8, 9 > 18, 17 > 14 > 3, 6 > 1 > 12, 15 > 7 > 16 > 10.

Table 5.10 China’s second phase option prioritization (Alhindi et al., 2017b), © 2017 IEEE

#	Short form of the preference statements	Preference Statements	Comments
1	1 & -2 & -3	Establishing the AIIB without accepting the US terms and the US and Japan do not join it.	The formation of the AIIB promotes China’s influence regionally and globally.
2	2 IF 4	Accept US terms over establishing the AIIB when the US offers them.	The increased contributions of China in the World Bank may appease the US since the US majorly influences it.
3	-5	The US does not oppose the AIIB	The opposition from the US may lead to lesser participants in the AIIB.
4	-6	The US does not launch the TPP	The launch of the TPP may reduce the Chinese influence in the region.

Table 5.11 The US’s second phase option prioritization (Alhindi et al., 2017b), © 2017 IEEE

#	Short form of the preference statements	Preference Statements	Comments
1	-1 & 6	China to remain at status quo and the US to launch the TPP	The US prefers that China does not take any action, and the TPP will promote US influence in the region.
2	2 IF 4	China to accept the US terms over the AIIB when proposed by the US	Increased contributions by China to the World Bank are preferred by the US, as the organization is highly influenced by it.
3	5 IF -2	Oppose the AIIB if China is not willing to accept the terms	This action may result in lesser participants in the AIIB, reducing Chinese influence in the region.
4	3 IF -2	Join the AIIB	China’s veto right in the AIIB could be nullified, given that the US and Japan join the AIIB together.

5.4.1.6 Reversible and Irreversible Moves:

In addition to the following assumptions for the option reversibility for each DM, the assumptions from the previous phase are also considered.

- China: The choice of accepting the US terms over the AIIB (i.e., Option 2) is reversible. This action can be exercised by China without any dependencies on other DMs; therefore, reversing this action is solely China's decision, which would mean that reversing it is a valid option for China. However, the consequences of reversing this move might possibly be very drastic.
- The United States:
 - The decision to request China to accept the US terms (Option 4) is reversible, as it is an independent decision for the US, which would allow the possibility of reversing this action.
 - The action to launch the TPP (Option 6) is irreversible, since withdrawing from such an agreement is a long and difficult process, as it may require the approval of the US Congress.

5.4.2 Stability Analysis of the Second Phase

The individual stability analysis for China and the US is shown in Tables 5.13 and 5.14 respectively, and the equilibrium states obtained by the implementation of the Nash, SEQ,

DM		States	4	5	6	8	9	15	17	18
China	Establish the AIIB		Y	Y	Y	Y	Y	Y	Y	Y
	Accept US terms over AIIB		N	Y	N	N	N	N	N	N
US	Join the AIIB		N	N	Y	N	N	Y	N	N
	Request China accept US terms		Y	Y	Y	N	Y	Y	N	Y
	Oppose the AIIB		N	N	N	Y	Y	N	Y	Y
	Launch the TPP		N	N	N	N	N	Y	Y	Y

Figure 5.1 SEQ stability analysis of state 5 with respect to China

GMR, SMR solution concepts are shown in Table 5.15. The analysis reveals that there is one weak equilibrium state (14) and six strong equilibria states (1, 5, 12, 15, 17, and 18). Moreover, since States 1 and 5 are SEQ equilibria and State 1 is the status quo at which the conflict will not have occurred, therefore State 5 can be considered as the most realistic and likely resolution of the conflict at this phase.

The SEQ solution concept considers a state to be in equilibrium if the given state is SEQ-stable for all the involved DMs. A state is identified as being SEQ-stable when the focal DM cannot take advantage of a UI to improve their situation and move to a more preferred state because the opponent has the ability to sanction the UI. As such, if the focal DM selects the

move, then the conflict will end up in a less preferred state for the focal DM. For example, if the conflict is at State 5, in Figure 5.1, China is tempted to improve its position in the conflict by reversing Option 2 by considering a UI to move to State 4, which is a more

		UI for The US		
DM	States	14	5	13
China	Establish the AIIB	Y	Y	Y
	Accept US terms over AIIB	Y	Y	N
US	Join the AIIB	N	N	N
	Request China accept US terms	Y	Y	Y
	Oppose the AIIB	N	N	N
	Launch the TPP	Y	N	Y

Figure 5.2 SEQ stability analysis of state 5 with respect to the US

preferred state than State 5 for the Chinese. However, if China moves to State 4 through its UI, then the US has the possibility of sanctioning the Chinese UI and moving to a state more preferred than State 4, US UIs from State 4 may lead to States 6, 8, 9, 15, 17, and 18 which are all less preferred than State 5 for China as shown in Figure 5.1. Therefore, State 5 is SEQ-stable for China. Figure 5.1 illustrates the SEQ stability for China.

State 5 is also identified to be SEQ-stable for the US. The US has a UI, by selecting the option to launch the TPP, to State 14, which is more preferred than State 5, as shown in Figure 5.2. However, China has the capability of sanctioning this UI by unselecting Option

2 (i.e., accepting the US terms over the AIIB), which leads to a less preferred state for the US.

Table 5.12 Second phase option form (Alhindi et al., 2017b), © 2017 IEEE

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
China	1	Establish the AIIB	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
	2	Accept the US terms over AIIB	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
	3	Join the AIIB	N	N	Y	N	N	Y	Y	N	N	N	N	Y	N	N	Y	Y	N	N
US	4	Request China to accept the US terms over AIIB	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y
	5	Oppose the AIIB	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y
	6	Launch the TPP	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Ranking		China	[2	4]	11	13	5	[8	9]	[17	18]	14	1	[3	6]	[12	15]	7	16	10
		US	10	1	14	5	16	[17	18]	13	[12	15]	[8	9]	7	6	11	3	[2	4]

Table 5.13 Second phase standard individual stability analysis for China

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
China	1	Establish the AIIB	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
	2	Accept US terms over AIIB	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
	3	Join the AIIB	N	N	Y	N	N	Y	Y	N	N	N	N	Y	N	N	Y	Y	N	N
US	4	Request China to accept the US terms over AIIB	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y
	5	Oppose the AIIB	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y
	6	Launch the TPP	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Ranking		China	[2	4]	11	13	5	[8	9]	[17	18]	14	1	[3	6]	[12	15]	7	16	10
		US	10	1	14	5	16	[17	18]	13	[12	15]	[8	9]	7	6	11	3	[2	4]
Individual Stability		Nash	-	✓	✓	✓	-	✓	-	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓
		SEQ	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓
		GMR	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓
		SMR	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓

Table 5.14 Second phase standard individual stability analysis for the US

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
China	1	Establish the AIIB	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
	2	Accept US terms over AIIB	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
	3	Join the AIIB	N	N	Y	N	N	Y	Y	N	N	N	N	Y	N	N	Y	Y	N	N
US	4	Request China to accept the US terms over AIIB	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y
	5	Oppose the AIIB	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y
	6	Launch the TPP	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Ranking	China		[2	4]	11	13	5	[8	9]	[17	18]	14	1	[3	6]	[12	15]	7	16	10
	US		10	1	14	5	16	[17	18]	13	[12	15]	[8	9]	7	6	11	3	[2	4]
Individual Stability	Nash		-	-	-	-	-	-	-	-	-	✓	-	✓	-	✓	✓	✓	✓	✓
	SEQ		✓	-	-	-	✓	-	✓	-	-	✓	-	✓	-	✓	✓	✓	✓	✓
	GMR		✓	-	-	-	✓	-	✓	-	-	✓	-	✓	-	✓	✓	✓	✓	✓
	SMR		✓	-	-	-	✓	-	✓	-	-	✓	-	✓	-	✓	✓	✓	✓	✓

Table 5.15 Second phase standard stability analysis – Equilibria (Alhindi et al., 2017b), © 2017 IEEE

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
China	1	Establish the AIIB	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
	2	Accept US terms over AIIB	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
	3	Join the AIIB	N	N	Y	N	N	Y	Y	N	N	N	N	Y	N	N	Y	Y	N	N
US	4	Request China to accept the US terms over AIIB	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y
	5	Oppose the AIIB	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y
	6	Launch the TPP	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
State Ranking	China		[2	4]	11	13	5	[8	9]	[17	18]	14	1	[3	6]	[12	15]	7	16	10
	US		10	1	14	5	16	[17	18]	13	[12	15]	[8	9]	7	6	11	3	[2	4]
Equilibria	Nash		-	-	-	-	-	-	-	-	-	-	-	✓	-	-	✓	-	✓	✓
	SEQ		✓	-	-	-	✓	-	-	-	-	-	-	✓	-	-	✓	-	✓	✓
	GMR		✓	-	-	-	✓	-	-	-	-	-	-	✓	-	✓	✓	-	✓	✓
	SMR		✓	-	-	-	✓	-	-	-	-	-	-	✓	-	✓	✓	-	✓	✓

5.4.3 Hypergame Investigation of the Second Phase

Section 5.2 revealed that some analysts claimed that the implementation of the TPP agreement would be beneficial to China. The TPP is a trade agreement which will eventually improve the economic prospects in the region, leading to an indirect benefit for China (Wang, 2016). Hence, the option of launching the TPP may prove to be a blessing in disguise for China, and that is the opposite of what is expected by both DMs. Henceforth, both China and the US are misperceiving their own preferences in terms of the TPP. The equilibrium states that result from the standard GMCR model investigation are valid only when genuine information regarding the effect of launching the TPP is not available for by the DMs. However, once the information is exposed, these equilibrium states will be invalid. Consequently, the conflict can be analyzed further by a hypergame model (Aljefri et al., 2014, 2017). A first-level hypergame model could be used to analyze the conflict, since both DMs are misperceiving their own preferences. For constructing the hypergame model, the option of launching the TPP is removed. Meanwhile, for the remaining options, the point in time, feasible and infeasible states, option prioritization for each DM, and reversible and irreversible moves continue to be the same as in the standard model.

5.4.3.1 Option Form:

The hypergame model is created by removing all the states that have the TPP option selected, since the option of launching the TPP is assumed to be invalid if the US recognizes that it is beneficial to China. Table 5.16 shows the option form of the hypergame, which consists of

9 states after removing the states where the option of launching the TPP is enabled. The states' preference rankings for each DM are listed in the lower part of Table 5.16, under the state's rankings, which are from most preferred to the left to least preferred to the right.

Table 5.16 Second phase hypergame option form (Alhindi et al., 2017b), © 2017 IEEE

		States	1	2	3	4	5	6	7	8	9
China	Establish the AIIB		N	Y	Y	Y	Y	Y	Y	Y	Y
	Accept the US terms over AIIB		N	N	N	N	Y	N	Y	N	N
US	Join the AIIB		N	N	Y	N	N	Y	Y	N	N
	Request China to accept the terms		N	N	N	Y	Y	Y	Y	N	Y
	Oppose the AIIB		N	N	N	N	N	N	N	Y	Y
State Ranking	China		[2	4]	[8	9]	5	1	[3	6]	7
	US		1	5	[8	9]	7	6	3	[2	4]

Table 5.17 Second phase hypergame individual stability analysis for China

		States	1	2	3	4	5	6	7	8	9
China	Establish the AIIB		N	Y	Y	Y	Y	Y	Y	Y	Y
	Accept US terms over		N	N	N	N	Y	N	Y	N	N
US	Join the AIIB		N	N	Y	N	N	Y	Y	N	N
	Request China to accept the terms		N	N	N	Y	Y	Y	Y	N	Y
	Oppose the AIIB		N	N	N	N	N	N	N	Y	Y
Individual Stability	Nash		-	✓	✓	✓	-	✓	-	✓	✓
	SEQ		✓	✓	✓	✓	✓	✓	-	✓	✓
	GMR		✓	✓	✓	✓	✓	✓	-	✓	✓
	SMR		✓	✓	✓	✓	✓	✓	-	✓	✓

5.4.3.2 Stability Analysis of the Hypergame:

The model is investigated via the same solution concepts that were applied to study the standard model. The individual stabilities are shown in Tables 5.17 and 5.18 for China and the US respectively. Table 5.19 demonstrates the equilibrium states predicted by the stability analysis after the elimination of launching the TPP option from the game. The results reveal that States 1, 5, 6, 8, and 9 are equilibrium states. States 1 and 5 are also identified as equilibrium states from the standard model’s investigation, while States 6, 8, and 9 are new emerging equilibria.

State 5 as shown in Table 5.19 is in SEQ, GMR, and SMR equilibrium. The same results were obtained from the standard model’s analysis, which further confirms that State 5 is the most probable resolution for this phase of the conflict.

Table 5.18 Second phase hypergame individual stability analysis for the US

		States	1	2	3	4	5	6	7	8	9
China	Establish the AIIB	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Accept US terms over	N	N	N	N	Y	N	Y	N	N	N
US	Join the AIIB	N	N	Y	N	N	Y	Y	N	N	N
	Request China to accept the terms	N	N	N	Y	Y	Y	Y	N	Y	Y
	Oppose the AIIB	N	N	N	N	N	N	N	Y	Y	Y
Individual Stability	Nash	✓	-	-	-	✓	✓	✓	✓	✓	✓
	SEQ	✓	-	-	-	✓	✓	✓	✓	✓	✓
	GMR	✓	-	-	-	✓	✓	✓	✓	✓	✓
	SMR	✓	-	-	-	✓	✓	✓	✓	✓	✓

Table 5.19 Second phase hypergame stability analysis – Equilibria (Alhindi et al., 2017b),

© 2017 IEEE

		States	1	2	3	4	5	6	7	8	9
China	Establish the AIIB		N	Y	Y	Y	Y	Y	Y	Y	Y
	Accept US terms over		N	N	N	N	Y	N	Y	N	N
US	Join the AIIB		N	N	Y	N	N	Y	Y	N	N
	Request China to accept the terms		N	N	N	Y	Y	Y	Y	N	Y
	Oppose the AIIB		N	N	N	N	N	N	N	Y	Y
State Ranking	China		[2	4]	[8	9]	5	1	[3	6]	7
	US		1	5	[8	9]	7	6	3	[2	4]
Equilibria	Nash		-	-	-	-	-	✓	-	✓	✓
	SEQ		✓	-	-	-	✓	✓	-	✓	✓
	GMR		✓	-	-	-	✓	✓	-	✓	✓
	SMR		✓	-	-	-	✓	✓	-	✓	✓

5.5 Post-Obama Era and Implementation of the Regional Comprehensive Economic Partnership

The third phase of the conflict between China and the US over the global trade agreements considers the period after the election and inauguration of Mr. Trump as the president of the US. Mr. Trump has signed an executive order to withdraw the US from the TPP, and the withdrawal of the US from the TPP has allowed China to emerge as the leader in global trade by the introduction of the RCEP agreement, as explained earlier in Section 5.2.

5.5.1 Model of Third Phase

5.5.1.1 Point in Time:

The point in time selected for the third phase is February 2017. By this time, Mr. Trump is the president of the US and has decided to withdraw from the TPP, while China was already engaged in negotiations for implementing the RCEP among the participating countries.

5.5.1.2 Decision-Makers:

The key DMs, i.e., China and the US, in the third phase are essentially the same as the previous phases. The background of the conflict section elaborated that Japan is, in fact, participating in the RCEP. Therefore, in this stage, Japan has a different vision in terms of their relationship with China. However, the option of joining the AIIB along with the US is still possible for Japan.

Table 5.20 Third phase DMs' options

DM	#	Options	Explanation
China	1	Continue the AIIB	China continues the AIIB while maintaining the highest international environmental and governance standards.
	2	Launch the RCEP	China and participating countries to implement the RCEP.
US	3	Join the AIIB	China's veto right in the AIIB could be revoked, given that the US and Japan join the AIIB together.

5.5.1.3 Decision-Makers' Options:

The options of establishing the AIIB by China and accepting the US terms over the AIIB, from the previous phase, are combined into a new option for China which is continuing with

the AIIB. China has one more addition to the options it controls, which is launching the RCEP. Moreover, the US has only one option at this point, which is joining the AIIB, as all other options from the previous phases are considered outdated. Table 5.20 lists the options that each DM can exercise along with the explanation of each option.

5.5.1.4 Option Form:

The option form is used to present the six feasible states of the model in Table 14. Similar to the option forms of the previous phases, the states have an entry of ‘Y’ for selected options and ‘N’ for unselected options. The lower part of Table 5.21, under the state rankings, shows the preference rankings for each state from most preferred on the left to least preferred on the right, where the states within the same brackets are equally preferred (e.g., for the US, the ranking is as follows: $1 > 2, 3 > 4 > 5 > 6$, where States 2 and 3 are indifferent and have the same priority). The feasible states were obtained after removing the infeasible states under the following assumption.

- China – The United States
 - Joining the AIIB for the US is dependent on China continuing with the AIIB. Therefore, the states in which Option 1 is not selected and Option 3 is chosen are removed.

Table 5.21 Third phase option form

DM	#	States (Ordered)	1	2	3	4	5	6
China	1	Continue the AIIB	N	Y	N	Y	Y	Y
	2	Launch the RCEP	N	N	Y	Y	N	Y
US	3	Join the AIIB	N	N	N	N	Y	Y

5.5.1.5 Decision Makers' Option Prioritization:

The option prioritization approach, which was explained earlier in the first phase of the conflict, is used to identify the states' preference rankings for each DM in the third phase, followed by manual sorting to mimic reality. Table 5.22 represents the option prioritization for the DMs involved in the conflict in a similar manner to that mentioned for the first phase of the conflict. Tables 5.23 and 5.24 show the preference rankings for China and the US in the third phase respectively.

Table 5.22 Third phase option prioritization

DM	#	Short form of the preference statements	Preference Statements	Comments
China	1	1 & 2 & -3	China to continue the AIIB and launch the RCEP, and the US does not join the AIIB.	Continuation of the AIIB and the launch of the RCEP will keep promoting China's influence regionally and globally.
	2	3	The US to join the AIIB	Refer to Table 5.1
	4	-1 & -2	China to remain at status quo	Refer to Table 5.1
US	5	-1 | -2	China to continue the AIIB or launch the RCEP	-
	6	1 & 2	China to continue the AIIB and launch the RCEP	-
	7	4	Join the AIIB	Refer to Table 5.1

5.5.1.6 Reversible and Irreversible Moves:

The options in the third phase are all related to establishing or joining organizations and partnerships. Actions to withdraw or pull out from these organizations and partnerships are difficult and have lengthy and complicated processes. Therefore, all the moves in this phase are assumed to be irreversible.

Table 5.23 Third phase preference ranking of states for China

DM	#	Options	Strategies					
China	1	Continue the AIIB	Y	Y	N	Y	Y	N
	2	Launch the RCEP	Y	N	Y	Y	N	N
US	3	Join the AIIB	N	N	N	Y	Y	N
State Ranking	China		4	2	3	6	5	1

Table 5.24 Third phase preference ranking of states for the US

DM	#	Options	Strategies					
China	1	Continue the AIIB	N	Y	N	Y	Y	Y
	2	Launch the RCEP	N	N	Y	Y	N	Y
US	3	Join the AIIB	N	N	N	N	Y	Y
State Ranking	US		1	[2	3]	4	5	6

5.5.2 Stability Analysis of the Third Phase

The investigations with respect to Nash, SEQ, GMR, and SMR solution concepts are shown individually for China and the US in Tables 5.25 and 5.26 respectively. The equilibrium states of the third phase forecasted by the stability analyses are illustrated in Table 5.27. The

analyses reveal that States 4 and 6 are strong equilibrium states since both are Nash equilibria.

Therefore, according to the model, the conflict may end up in one of these states.

The conflict has yet to reach its resolution in real life. However, considering the current situation, it may end up in State 4, where China continues with the AIIB and launches the RCEP while the US does nothing. One more thing to note is that State 4 is the only strong equilibrium if the move to join the AIIB is assumed as reversible.

Table 5.25 Third phase individual stability analysis for China

DM	#	States (Ordered)	1	2	3	4	5	6
China	1	Continue the AIIB	N	Y	N	Y	Y	Y
	2	Launch the RCEP	N	N	Y	Y	N	Y
US	3	Join the AIIB	N	N	N	N	Y	Y
State Ranking		China	4	2	3	6	5	1
		US	1	[2	3]	4	5	6
Individual Stability		Nash	-	-	-	✓	-	✓
		SEQ	-	-	-	✓	-	✓
		GMR	-	✓	✓	✓	-	✓
		SMR	-	✓	✓	✓	-	✓

Table 5.26 Third phase individual stability analysis for the US

DM	#	States (Ordered)	1	2	3	4	5	6
China	1	Continue the AIIB	N	Y	N	Y	Y	Y
	2	Launch the RCEP	N	N	Y	Y	N	Y
US	3	Join the AIIB	N	N	N	N	Y	Y
State Ranking		China	4	2	3	6	5	1
		US	1	[2 3]		4	5	6
Equilibria		Nash	✓	✓	✓	✓	✓	✓
		SEQ	✓	✓	✓	✓	✓	✓
		GMR	✓	✓	✓	✓	✓	✓
		SMR	✓	✓	✓	✓	✓	✓

Table 5.27 Third phase stability analysis - Equilibria

DM	#	States (Ordered)	1	2	3	4	5	6
China	1	Continue the AIIB	N	Y	N	Y	Y	Y
	2	Launch the RCEP	N	N	Y	Y	N	Y
US	3	Join the AIIB	N	N	N	N	Y	Y
State Ranking		China	4	2	3	6	5	1
		US	1	[2 3]		4	5	6
Equilibria		Nash	-	-	-	✓	-	✓
		SEQ	-	-	-	✓	-	✓
		GMR	-	✓	✓	✓	-	✓
		SMR	-	✓	✓	✓	-	✓

5.6 Options Effectiveness

The proposed approach is applied on the GMCR model that was constructed to analyze the conflict between the US and China over global trade agreements (Alhindi et al., 2017a, b; 2018b). The conflict was divided into three phases and a GMCR model was established for each phase.

5.6.1 First Phase Option Effectiveness

The first phase of the conflict under study started when China proposed the initiative to launch the AIIB in 2013, an initiative that would strengthen China's position in the world's economic politics. The US had two alternatives at the time, either to join the AIIB or oppose it and lobby its allies against being part of it. As explained in Chapter 3, the Option Effectiveness approach is divided into two major steps. The first step is to calculate the strength of the equilibrium states and the second step is to measure the option effectiveness. The stability analysis that was done using the GMCR model of the first phase will be the basis of measuring the Option Effectiveness for the first phase of the conflict.

The strength of equilibria calculations can be carried out using Equation 3.1 for each of the equilibrium states, and will be used to compute the Option Effectiveness. To start, one needs to ascertain the solution concept under which an equilibrium state is an equilibrium. Strength points for a state are assigned based on the solution concepts under which the state is equilibrium. For instance, if a state is in equilibrium under Nash stability then is it given 4 points; 3 points for SEQ equilibrium; 2 points for SMR equilibrium; and 1 point for GMR

equilibrium, as indicated in Table 3.2. For a given equilibrium state, all these points are accumulated using Equation 3.1. Table 5.28 shows the tabular approach for calculating the strength of equilibrium states in the first phase of this conflict. The middle four columns in the table under Nash, SEQ, SMR, and GMR solution concepts show the type of the equilibrium, where “1” is entered for the states that are equilibrium under that stability definition and “0” otherwise. The last column in Table 5.28 displays the strength of equilibrium states. The stability analysis of the first phase conflict model revealed two equilibrium states, which are Nash, SEQ, SMR, and GMR equilibria. Hence, both states accumulated 10 strength points.

Table 5.28 Strength of Equilibria calculation for the first phase GMCR model of the conflict between China and the US over global trade agreements

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_3$	1	1	1	1	10
$E_2 = S_4$	1	1	1	1	10

The Option Effectiveness computation, Equation 3.2, can be carried out once the strengths of all equilibrium states have been identified. For a given option, the Option Effectiveness is calculated by summing the strengths of all the equilibrium states in which the option is selected. Table 5.29 explains the option selection occurrences and the effectiveness of each option in the conflict. The option selection is presented by “1”, for selected, and “0”

otherwise, next to each equilibrium state row-wise, and under a given option column-wise. The last column in the table summarizes the strength of the equilibrium state extracted from Table 5.28, and the last row in Table 5.29 lists the Option Effectiveness value for each option in the conflict model.

For instance, Option 1, denoted by O_1 , establishing the AIIB by China, is selected under both equilibrium states of the first phase. Therefore, its option effectiveness is calculated by summing $STR(S_3)$ and $STR(S_4)$, as shown in the first column of Table 5.28, and can be mathematically expressed as:

$$EFF(O_1) = a_{11} STR(S_3) + a_{21} STR(S_4) = (1) * 10 + (1) * 10 = 20$$

The same approach is followed to calculate the effectiveness of the remaining options in the model. As indicated in Table 5.29, Option 1 has an option effectiveness value of 20; Option 2, joining the AIIB by the US and Japan, has an option effectiveness value of 10; and Option 3, opposing the AIIB by the US, has a total option effectiveness value of 10. Option 1 can be considered as the main reason for the conflict, and it achieved the highest option effectiveness. Meanwhile, Options 2 and 3 have a tie in their effectiveness, as both achieved the same value, meaning that either of these options is likely to be part of the final resolution, along with Option 1.

Historically, in this phase of the dispute China was well on its way to establishing the AIIB. In the meantime, the US, along with Japan, was lobbying to keep its allies from joining the AIIB.

Table 5.29 Tabular approach for computing the Option Effectiveness for the first phase GMCR model of the conflict between China and the US over global trade agreements

	O_1	O_2	O_3	Strength of Equilibrium
$E_1 = S_3$	1	1	0	10
$E_2 = S_4$	1	0	1	10
Option Effectiveness	20	10	10	

5.6.2 Second Phase Option Effectiveness

The conflict model of the second phase includes six options. Two of these options are controlled by China and the remainder by the US. The general option form of the conflict, including the available options and the preference ranking for each DM, is shown in Table 5.12. The stability analysis of the second phase model found seven equilibrium states, as shown in Table 5.13. For calculating the Option Effectiveness of this GMCR model, the strength of each equilibrium state needs to be computed. Therefore, the first step is to assign strength points to each equilibrium state, denoted by $STR(E)$, as shown in Table 5.30, based on the criteria shown in Table 3.2, by applying Equation 3.1. Table 5.30 lists the strengths of the equilibrium states in the last column. The strong equilibrium states, States 12, 15, 17, and 18, have 10 strength points, since they are found to be Nash, SEQ, SMR, and GMR equilibria. Meanwhile, States 1 and 5 are SEQ, SMR, and GMR equilibria and have 6 strength points each. State 14 is the weakest equilibrium in the conflict model and has only 3 strength points.

Table 5.30 Strength of Equilibria calculation for the second phase standard GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c),
© 2018 IEEE

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_1$	0	1	1	1	6
$E_2 = S_5$	0	1	1	1	6
$E_3 = S_{12}$	1	1	1	1	10
$E_4 = S_{14}$	0	0	1	1	3
$E_5 = S_{15}$	1	1	1	1	10
$E_6 = S_{17}$	1	1	1	1	10
$E_7 = S_{18}$	1	1	1	1	10

Accordingly, the effectiveness of each option in the conflict model can be computed using Equation 3.2 by summing up the strength of the equilibrium states in which a given option is selected. Table 5.31 illustrates the tabular approach for calculating the Option Effectiveness. Therefore, the effectiveness of Option 1, establishing the AIIB by China, is

$$\begin{aligned}
 EFF(O_1) &= a_{21} STR(S_5) + a_{31} STR(S_{12}) + a_{41} STR(S_{14}) + a_{51} STR(S_{15}) + a_{61} STR(S_{17}) \\
 &\quad + a_{71} STR(S_{18}) = (1) * 6 + (1) * 10 + (1) * 3 + (1) * 10 + (1) * 10 + (1) * 10 \\
 &= 49
 \end{aligned}$$

Table 5.31 Tabular approach for computing the Option Effectiveness for the second phase standard GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE

	O_1	O_2	O_3	O_4	O_5	O_6	Strength of Equilibrium
$E_1 = S_1$	0	0	0	0	0	0	6
$E_2 = S_5$	1	1	0	1	0	0	6
$E_3 = S_{12}$	1	0	1	0	0	1	10
$E_4 = S_{14}$	1	1	0	1	0	1	3
$E_5 = S_{15}$	1	0	1	1	0	1	10
$E_6 = S_{17}$	1	0	0	0	1	1	10
$E_7 = S_{18}$	1	0	0	1	1	1	10
Option Effectiveness	49	9	20	29	20	43	

The Option Effectiveness for the remaining options in the conflict can be similarly calculated. Option 1 has the highest effectiveness, since it contributes to six of the seven equilibrium states. An argument can be made that this option is essentially the reason for the conflict; the conflict probably would not exist if this option was removed. Furthermore, Option 6, launching the TPP agreement by the US, has an effectiveness value of 43, which is the 2nd-highest among all the options, indicating that it is the most effective counter-move by the US. Option 4, requesting China to accept the terms offered by the US, is ranked 3rd, with an effectiveness value of 29. In the meantime, the 4th rank in terms of option effectiveness belongs to Option 3, the US to join the AIIB, and Option 5, the US to oppose the AIIB, indicating a tie. Surprisingly, these two options had the same effectiveness ranking in the first phase as well. The least effective action in the second phase is Option 2, China

accepting the US terms over the AIIB. Option 2 being the least effective option makes sense, since it puts China under US influence by accepting the terms over the AIIB while also increasing their contribution to the World Bank, rather than having the freedom to do so of their own will. Another thing to note is that this option is dependent on Option 5, meaning that it can only be selected if Option 5 is selected by the US.

The hypergame analysis of the second phase of this conflict has shown that the TPP's effects are misperceived by both DMs, China and the US, and therefore these resolutions are compromised and are only valid if the real information about the TPP is inaccessible for the DMs. Hence, to accurately analyze the second phase of the conflict, the Option Effectiveness approach needs to be applied on the hypergame model of the second phase.

The hypergame investigation, in which the option of launching the TPP by the US is removed, predicted five equilibrium states. Table 5.17 shows the stability analysis of the hypergame model for the second phase of the conflict. States 6, 8, and 9 were all found to be Nash, SEQ, SMR, and GMR equilibria, whereas States 1 and 5 are SEQ, SMR, and GMR equilibria. Strength points can be assigned to each of the equilibrium states in the hypergame conflict model in the second phase based on the criteria mentioned in Table 3.2. By applying Equation 3.1, States 6, 8, and 9 are assigned 10 strength points each, since they are in equilibrium under each of the Nash, SEQ, SMR, and GMR solution concepts. Meanwhile, States 1 and 5 accumulate 6 strength points each, as they are SEQ, SMR, and GMR equilibria.

Table 5.32 shows the strength of equilibria calculations of the hypergame model and the associated strength points given to each equilibrium.

Table 5.32 Strength of Equilibria calculation for the second phase hypergame GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_1$	0	1	1	1	6
$E_2 = S_5$	0	1	1	1	6
$E_3 = S_6$	1	1	1	1	10
$E_4 = S_8$	1	1	1	1	10
$E_5 = S_9$	1	1	1	1	10

The Option Effectiveness is calculated using Equation 3.2 for the hypergame model, and the tabular approach for calculating it for the hypergame is shown in Table 5.33. Similar to the Option Effectiveness of the standard GMCR model of the second phase, Option 1, establishing the AIIB by China, has the highest effectiveness and is found to be the root of the dispute. However, the 2nd-highest effectiveness is achieved by Option 4, the US offering China terms over the AIIB, which is selected in three of the five equilibrium states, and in fact, in real life, this option was the reason that the US withheld its opposition after the Chinese acceptance of the US terms over the AIIB. By accepting these terms, China had to increase its contributions to the World Bank. The 3rd-highest effectiveness is achieved by Option 5, opposing the AIIB, and it is controlled by the US, whereas the 4th-highest

effectiveness is reached by Option 3, the US joining the AIIB. The ranking order of Option 5 and Option 3 means that Option 5 is more effective than Option 3, which is why the US opposed the AIIB as mean to press China in accepting their terms over the AIIB rather than joining the AIIB itself.

The counter-move, opposing the AIIB, exercised by the US was successful, and it lured China into accept the US terms, which may not have been the case if the US had joined the AIIB. Similar to the option effectiveness of the standard GMCR model of the second phase, the least effective option in the hypergame model is Option 2, China accepting the US terms over the AIIB, since it only contributed to a single equilibrium state. As mentioned earlier, Option 2 being the least effective option can rather be justified, as it allows the US to impose terms on China and force it to increase its contributions to the World Bank.

Table 5.33 Tabular approach for computing the Option Effectiveness for the second phase hypergame GMCR model of the conflict between China and the US over global trade agreements (Alhindi et al., 2018c), © 2018 IEEE

	O_1	O_2	O_3	O_4	O_5	Strength of Equilibrium
$E_1 = S_1$	0	0	0	0	0	6
$E_2 = S_5$	1	1	0	1	0	6
$E_3 = S_6$	1	0	1	1	0	10
$E_4 = S_8$	1	0	0	0	1	10
$E_5 = S_9$	1	0	0	1	1	10
Option Effectiveness	36	6	10	26	20	

5.6.3 Third Phase Option Effectiveness

The third phase of the conflict has some options combined, another newly introduced, and some removed. The options to establish the AIIB and to accept the US terms over the AIIB, both controlled by China, are combined into continuation of the AIIB, and which is controlled by China. The new option, controlled by China, is to Launch the RCEP. As for the US, all the options were eliminated from the conflict model besides the option to join the AIIB, as described previously, resulting in a conflict model with only three options in total.

The stability analysis of the third phase, shown in Table 5.27, indicates that there are four equilibrium states, in which States 4 and 6 are Nash, SEQ, SMR, and GMR equilibrium and States 2 and 3 are SMR and GMR equilibrium only. Therefore, by applying Equation 3.1, the strength of equilibrium States 4 and 6 is 10 strength points each, whereas equilibrium States 2 and 3 have 3 strength points each. Table 5.34 illustrates the tabular approach for calculating strengths of equilibrium for the third phase of the conflict.

Table 5.34 Strength of Equilibria calculation for the third phase GMCR model of the conflict between China and the US over global trade agreements

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_2$	0	0	1	1	3
$E_2 = S_3$	0	0	1	1	3
$E_3 = S_4$	1	1	1	1	10
$E_4 = S_6$	1	1	1	1	10

Subsequently, the option effectiveness for an option in the third phase of the conflict can be calculated by summing up the strength of the equilibrium states in which that option has been selected. For example, the option effectiveness for Option 1, China to continue with the AIIB, can be calculated using Equation 3.2 and can be expressed mathematically as:

$$EFF(O_1) = a_{11} STR(S_2) + a_{31} STR(S_4) + a_{41} STR(S_6) = (1) * 3 + (1) * 10 + (1) * 10 = 23$$

Accordingly, the effectiveness of the remaining option can be computed in a similar manner. Table 5.35 explains the tabular approach for calculating the effectiveness of the options involved in the third phase of the conflict. Option 1, China to continue with the AIIB, and Option 2, launching the RCEP by China, are both ranked as the most effective options in the conflict, since both scored an effectiveness value of 23. Meanwhile, Option 3, the US and Japan to join the AIIB, is ranked the least effective, only accumulating a value of 10. However, one can argue that the importance of unselecting the option could be included. In fact, in this case, the action of unselecting Option 3 is deemed to be more effective than selecting it. The strategies or equilibrium states in which Option 3 is unselecting are States 2, 3, and 4, which have 3, 3, and 10 strength points respectively. Therefore, the action of unselecting Option 3 will result in an effectiveness value of 16 when applying Equation 3.2, and consequently, the action of unselecting Option 3 is ranked higher than choosing Option 3 for the US in terms of effectiveness.

In the third phase of the conflict, China has continued its endeavor in running the AIIB and is seriously considering the launch of the RCEP trade agreement as well. In the

meantime, the US has neglected the idea of participating in the AIIB. The historic events of the conflict justify the ranking of the options involved with respect to Option Effectiveness, especially for the case of the US unselecting Option 3 in comparison to choosing it.

Table 5.35 Tabular approach for computing the Option Effectiveness for the third phase GMCR model of the conflict between China and the US over global trade agreements

	O_1	O_2	O_3	Strength of Equilibrium
$E_1 = S_2$	1	0	0	3
$E_2 = S_3$	0	1	0	3
$E_3 = S_4$	1	1	0	10
$E_4 = S_6$	1	1	1	10
Option Effectiveness	23	23	10	

5.7 Overall Strategic Insights

The stability analysis of the first phase indicated that States 3 and State 4 are possible resolutions for that point in time. Moreover, if the move to join the AIIB by the US and Japan is considered reversible, then State 4 is the only equilibrium for the first phase of the conflict. In State 4, China establishes the AIIB and the US opposes it while lobbying its allies against joining it, which represents the exact resolution for that period in real life.

The standard GMCR and hypergame investigation of the models for the second phase indicates that State 5 could be a resolution, where China forms the AIIB and acknowledges the US terms over the AIIB. Moreover, State 5 is identical to the situation under the Obama Administration in the US, in which China established the AIIB and accepted the US terms regarding the AIIB. Meanwhile, the US stopped their opposition towards the AIIB and did

not launch the TPP agreement. The hypergame analysis shows that the Trump administration was right about withdrawing from the TPP. The conflict reached a temporary resolution in State 4 in the Trump Administration era, where China has established the AIIB and is looking forward to launching the RCEP.

The investigation reveals that China might become the leader in global trade and fill the gap caused by the US by its withdrawal from the TPP, given that the Trump administration does not consider an alternative for the TPP. Moreover, the conflict between the US and China is a major conflict in the 21st century, and does not seem to be ending anytime soon. It can actually be considered a long-term conflict, since changes in governments and leadership within these countries will significantly affect the outcomes of the conflict (Matbouli et al., 2015).

The models developed for the three different points in time indicate that it is possible for a DM to include an option for influencing other DMs' preferences. This results in a change of the states' preference rankings for the DMs, which may ultimately cause the equilibrium to shift to another state. These new equilibrium states may be desired resolutions for the DM that influenced the preferences. In the current study, the US included the option of launching the TPP and offering to negotiate terms with China over the establishment of the AIIB in exchange for a truce over the AIIB in the second phase. These new options caused a change in preferences for the DMs and shifted the equilibrium to other states which are more practical and desirable for the US. However, in the third phase, China had a new option, that

of establishing the RCEP trade agreement, which changed the preferences for the DMs and caused a shift in the equilibrium, leading to desirable resolutions for the Chinese.

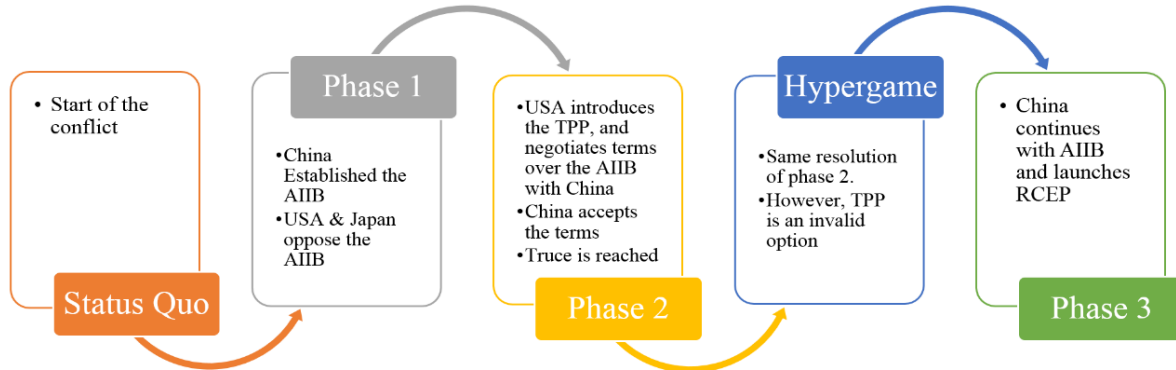


Figure 5.3 Historical evolution of the conflict over the three phases

Table 5.36 Evolution of the conflict over the three phases

		Status Quo	Phase 1		Phase 2		Hypergame	Phase 3
				Equilibrium		Equilibrium	Equilibrium	Equilibrium
China	Establish the AIIB	N → Y	Y	Y	Y	Y		
	Accept US terms over AIIB	N		N → Y	Y	Y		
	Continue the AIIB	N					Y	
	Launch RCEP	N					Y	
US	Join the AIIB	N	N	N	N	N	N	
	Request China to accept the US terms over AIIB	N		Y	Y	Y		
	Oppose the AIIB	N	N → Y	Y → N	N	N		
	Launch the TPP	N		Y	Y			

The novel approach of measuring option effectiveness has been applied to the three phases of the conflict between China and the US over global trade agreements. It demonstrates the

capability of the approach in investigating the conflict model at the option level. The ranking of the options with respect to their effectiveness could indicate the option causing the conflict, the best counter-moves, and the least important option(s). Moreover, it permits the effective comparison of a single option in terms of choosing it or unselecting it, as demonstrated in the case of Option 3 in the third phase of the conflict.

Figure 5.3 illustrates the evolution of the conflict, and Table 5.36 presents the evolution of the conflict, starting from the left and ending at the right end of the table, as well as the equilibrium changes affected by the addition and removal of options by the DMs over the course of the conflict. The dark gray-colored cells in the table show that the colored options are excluded from the conflict in that phase. The arrows in the table indicate a change in the status of the options. The table reveals that the conflict starts when China establishes the AIIB and reaches State 2 of the first phase and then the US opposes the AIIB, a move that resolves the conflict at State 4 in the first phase. The US then introduces the options of proposing terms to China over the AIIB and launching the TPP, which is referred to as the second phase of the conflict in the present study. In this phase, the US requests China to accept terms over the AIIB in exchange for a truce and the withdrawal of US opposition over the AIIB, China agrees to the US terms, and the conflict reaches a resolution at State 5 in the second phase in both GMCR and the hypergame models. In the third phase of the conflict, the options for establishing the AIIB and accepting the US terms are combined into a single option mentioned as continuing the AIIB for China, whereas launching the RCEP is a new

option introduced for China. Meanwhile, the US is only left with the option to join the AIIB. The conflict reaches a temporary equilibrium in the third phase in State 4, where China continues with the AIIB and works toward launching the RCEP agreement while the US remains calm and does nothing to counter-move.

5.8 Summary

The GMCR methodology and the Option Effectiveness advancement has been demonstrated by applying it to the three phases in time of the trade dispute between China and the US. The first phase of the conflict started in 2013 when China announced the establishment of the AIIB, and the US has countered it by lobbying its allies against joining it. The stability analysis predicted two equilibria at this phase. The Option Effectiveness has indicated that the option to establish the AIIB is the main reason behind this conflict. At the second stage of the conflict, which starts when the US proposed its terms to China over the AIIB, several equilibrium states were recognized as well as the resolution that occurred in real-world was identified. The Option Effectiveness procedure revealed that the establishing the AIIB still was the primary cause of the dispute and launching the TPP by the US was the best counter-move. However, the application of the Option Effectiveness to the hypergame model, which removes the TPP option from the conflict model, showed that offering US terms to China over the AIIB would be the best move by the US. Four equilibria were revealed at the third stage of the conflict, which starts after Mr. Donald Trump's inauguration as the President of the US. In this phase, he withdrew the US from the TPP trade agreement, and China was

working on launching the RCEP trade agreement. The Option Effectiveness approach confirms that the US act of not participating in the AIIB has a higher impact in resolving the conflict rather than joining it. The procedure has also revealed that launching the RCEP and continuing with the AIIB are two significant steps for the Chinese to resolve this trade conflict in their favor. China appears to be well on its way to overshadow US economic supremacy if the US does not fill the economic leadership void caused by its withdrawal from the TPP.

Chapter 6

Option Effectiveness: Case Studies

The Option Effectiveness approach is demonstrated further by applying it to the models of real-world conflicts such as the Elmira Conflict (Hipel, Kilgour, Fang, & Peng, 1999), the Cuban Missile Crisis (Fraser & Hipel, 1982, 1984; Hipel, 2011), and the Garrison Diversion Unit conflict (Fraser & Hipel, 1984). These applications will allow a concrete evaluation of the Option Effectiveness method and its practicality in investigating real-world conflict models at the option level.

6.1 Elmira Groundwater Contamination Conflict

The Elmira groundwater contamination conflict started in late 1989 in the town of Elmira, located in southwestern Ontario, Canada. The town, which lies in an agricultural region, is close to three of the Great Lakes and relies on an underground aquifer for its municipal water supply. The aquifer was found to be contaminated by a carcinogen, N-nitroso dimethylamine (NDMA), in an investigation carried out by the Ontario Ministry of Environment (MoE) in late 1989. Uniroyal Chemical Ltd. (Uniroyal) had a production plant for pesticides and rubber products in the area, which was considered as the likely source of the contaminating agent in the aquifer. Moreover, Uniroyal had previous environmental issues and was associated with processes for producing NDMA (Hipel et al., 1999).

A control order was issued by the MoE under the Environment Protection Act of Ontario that required Uniroyal to correct the problem by carrying out studies to evaluate the necessity

for a cleanup, conducting any required cleanup under the supervision of MoE, and implementing a long-term system that guaranteed the safe collection and treatment of waste. An appeal was filed immediately by Uniroyal against the MoE. Moreover, the Regional Municipality of Waterloo and the Township of Woolwich (local governments) had a significant role in the dispute and took a common stance in the conflict, in which they recruited consultants and acquired legal advice about the situation at a considerable price (Hipel et al., 1999).

Negotiations among the participating DMs in the dispute started in mid-1991. The participants were, as described earlier, MoE, Uniroyal, and the local governments. Every DM had a goal that they wanted to achieve. For instance, the MoE's goal was to continue carrying out its order; Uniroyal was seeking to alter or overturn the order; and the local governments' objective was to safeguard their inhabitants and the industrial sector (Hipel et al., 1999).

6.1.1 The Conflict Model

This conflict model constitutes three DMs, MoE, Uniroyal, and local governments, with each having its own objective in the conflict, as explained earlier. Certain options were considered for each DM. For instance, the MoE had the option to modify its mandate; Uniroyal's options constituted of delaying the process, accepting the mandate, or abandoning the plant; and the local governments had only one option, which was to insist on carrying out the mandate put forward by the MoE. Table 6.1 shows the option form of the conflict where

all the options are listed next to the DM that controlled it. The preference ranking of the states for MoE, Uniroyal, and local governments are shown in Tables 6.2, 6.3, and 6.4 respectively. These preference rankings were obtained directly from the study published by Hipel et al. in 1999.

Table 6.1 Option form of the Elmira Groundwater water contamination conflict

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9
MoE	1	Modify	N	Y	N	Y	N	Y	N	Y	-
	2	Delay	Y	Y	N	N	Y	Y	N	N	N
Uniroyal	3	Accept	N	N	Y	Y	N	N	Y	Y	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	N	N	N	N	Y	Y	Y	Y	-

Table 6.2 Preference ranking of MoE in the Elmira groundwater water contamination conflict

DM	#	Options	Strategies								
MoE	1	Modify	N	N	Y	Y	N	N	Y	Y	-
	2	Delay	N	N	N	N	Y	Y	Y	Y	N
Uniroyal	3	Accept	Y	Y	Y	Y	N	N	N	N	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	Y	N	N	Y	Y	N	N	Y	-
Preference (Ordered)			7	3	4	8	5	1	2	6	9

Table 6.3 Preference ranking of Uniroyal in the Elmira groundwater water contamination conflict

DM	#	Options	Strategies								
MoE	1	Modify	N	Y	Y	N	-	N	N	Y	Y
	2	Delay	Y	N	N	Y	N	N	N	Y	Y
Uniroyal	3	Accept	N	Y	Y	N	N	Y	Y	N	N
	4	Abandon	N	N	N	N	Y	N	N	N	N
Local Governments	5	Insist	N	N	Y	Y	-	N	Y	N	Y
Preference (Ordered)			1	4	8	5	9	3	7	2	6

Table 6.4 Preference ranking of Local Governments in the Elmira groundwater water contamination conflict

DM	#	Options	Strategies								
MoE	1	Modify	N	N	N	N	Y	Y	Y	Y	-
	2	Delay	N	N	Y	Y	N	Y	N	Y	N
Uniroyal	3	Accept	Y	Y	N	N	Y	N	Y	N	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	Y	N	Y	N	Y	Y	N	N	-
Preference (Ordered)			7	3	5	1	8	6	4	2	9

6.1.2 Stability Analysis

The individual stability analysis of the conflict model was carried out using GMCR+ (Kinsara et al., 2015b). The results are identical to what was obtained by the study conducted by Hipel et al. in 1999. Tables 6.5, 6.6, and 6.7 show the individual stability analysis results for the MoE, Uniroyal, and local governments respectively. These results are used to determine the equilibrium states of the conflict model, as shown in Table 6.8.

Table 6.5 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to MoE

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9
MoE	1	Modify	N	Y	N	Y	N	Y	N	Y	-
	2	Delay	Y	Y	N	N	Y	Y	N	N	N
Uniroyal	3	Accept	N	N	Y	Y	N	N	Y	Y	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	N	N	N	N	Y	Y	Y	Y	-
		Nash	✓	✓	✓	✓	✓	✓	✓	✓	✓
Solution concepts		SEQ	✓	✓	✓	✓	✓	✓	✓	✓	✓
		SMR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		GMR	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 6.6 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to Uniroyal

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9
MoE	1	Modify	N	Y	N	Y	N	Y	N	Y	-
	2	Delay	Y	Y	N	N	Y	Y	N	N	N
Uniroyal	3	Accept	N	N	Y	Y	N	N	Y	Y	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	N	N	N	N	Y	Y	Y	Y	-
		Nash	✓	-	-	✓	✓	-	-	✓	✓
		SEQ	✓	-	-	✓	✓	-	-	✓	✓
Solution concepts		SMR	✓	-	-	✓	✓	-	-	✓	✓
		GMR	✓	-	-	✓	✓	-	-	✓	✓

Table 6.7 Individual stability analysis of the Elmira groundwater water contamination conflict with respect to Local Governments

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9
MoE	1	Modify	N	Y	N	Y	N	Y	N	Y	-
	2	Delay	Y	Y	N	N	Y	Y	N	N	N
Uniroyal	3	Accept	N	N	Y	Y	N	N	Y	Y	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	N	N	N	N	Y	Y	Y	Y	-
		Nash	-	-	-	-	✓	✓	✓	✓	✓
		SEQ	-	✓	✓	-	✓	✓	✓	✓	✓
Solution concepts		SMR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		GMR	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 6.8 Stability analysis of the Elmira groundwater water contamination conflict showing the equilibrium states

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9
MoE	1	Modify	N	Y	N	Y	N	Y	N	Y	-
	2	Delay	Y	Y	N	N	Y	Y	N	N	N
Uniroyal	3	Accept	N	N	Y	Y	N	N	Y	Y	N
	4	Abandon	N	N	N	N	N	N	N	N	Y
Local Governments	5	Insist	N	N	N	N	Y	Y	Y	Y	-
		Nash	-	-	-	-	✓	-	-	✓	✓
		SEQ	-	-	-	-	✓	-	-	✓	✓
Solution concepts		SMR	✓	-	-	✓	✓	-	-	✓	✓
		GMR	✓	-	-	✓	✓	-	-	✓	✓

6.1.3 Strength of Equilibria

Stability analysis is a key component of the Option Effectiveness methodology, as mentioned in Chapter 3. The results obtained by the stability analysis of the conflict model are used as a basis to calculate the strength of the equilibria and the option effectiveness. Equation 3.1 is applied to calculate the strength of each equilibrium state, and Table 6.9 shows the strength of the equilibrium states in the last column to the right. The type of an equilibrium state is shown under Nash, SEQ, SMR, and GMR solution concepts columns in Table 6.9, where “1” indicates that the state is equilibrium under the solution concept and “0” indicates that its not an equilibrium with regards to that stability definition. States 1 and 4 have a strength

value of 3 due to only being equilibrium states under SMR and GMR stability concepts, while States 5, 8, and 9 have a strength value of 10 since they are Nash, SEQ, SMR, GMR equilibria.

Table 6.9 Strength of Equilibria calculation of the Elmira groundwater water contamination conflict model

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_1$	0	0	1	1	3
$E_2 = S_4$	0	0	1	1	3
$E_3 = S_5$	1	1	1	1	10
$E_4 = S_8$	1	1	1	1	10
$E_5 = S_9$	1	1	1	1	10

6.1.4 Option Effectiveness

Option effectiveness can only be calculated after the computation of the equilibria strengths. Therefore, the results shown in Table 6.9 are used for measuring the option effectiveness for each option in the conflict using Equation 3.2. Option 1 and Option 5 in State 9 can either be selected or unselected, and therefore they are given a constant value of 0.5 which is to be multiplied by the strength of State 9. Table 6.10 summarized the Option Effectiveness calculations for all the options in the model. The option selection is presented by “1”, for chosen, and “0”, for unselected, next to each equilibrium state row-wise, and under a given option, column-wise. The last column in the table lists the strength of the equilibrium state

extracted from Table 6.9, and the last row in Table 6.10 shows the option effectiveness each option in the conflict model.

The highest importance based on Equation 3.2 is achieved by Option 5, which is the option to insist on the mandate by the Local Governments; Option 1, modify the order, controlled by MoE, is ranked 2nd in terms of importance. A tie for the 3rd rank has occurred for Option 2, delay the process, and Option 3, accept the mandate, which are controlled by Uniroyal. Option 4, Uniroyal abandoning the plant, is considered the least important based on option effectiveness.

Table 6.10 Option Effectiveness calculation of the Elmira groundwater water contamination conflict model

	O_1	O_2	O_3	O_4	O_5	Strength of Equilibrium
$E_1 = S_1$	0	1	0	0	0	3
$E_2 = S_4$	1	0	1	0	0	3
$E_3 = S_5$	0	1	0	0	1	10
$E_4 = S_8$	1	0	1	0	1	10
$E_5 = S_9$	- (0.5)	0	0	1	- (0.5)	10
Option Effectiveness	18	13	13	10	25	

For an extended period of time State 5 was the resolution of the conflict at which Option 2 and Option 5 are selected by the relevant DMs. However, due to a coalition between the MoE and Uniroyal, the resolution shifted to State 8, where Options 1, 3, and 5 are selected. It can be noticed that Option 5, which is to insist on the mandate by the local governments,

has the highest importance ranking, is selected in both equilibrium states. Meanwhile, Option 4 is not chosen in any of the real-world resolutions. Thus, Option 5 having the highest importance and Option 4 having the lowest effectiveness in the dispute is justified.

6.2 The Cuban Missile Crisis

The United States (US) had complete control over Cuba politically and economically prior to 1957. The control was achieved by influencing the government of Fulgencio Batista. Cuba was also a hub for many American agricultural and tourism companies. However, in late 1956 an uprising by Fidel Castro began in order to remove Batista's regime and overthrow his government. Castro was successful in seizing control of Cuba in 1959. During this time, the Cuban government leaned towards an alliance with the Soviet Union (USSR); all American property was nationalized and many American economic investments were lost, making Cuba a hot issue in the US (Fraser & Hipel, 1982, 1984; Hipel, 2011).

In April 1961, Cuban exiles began the Bay of Pigs invasion with the backing of the US. However, the invasion failed as US President Kennedy withdrew support after the USSR threatened to support Cuba in defending itself, including supplying missiles to the Cuban military, even if it meant a nuclear war between the US and USSR. Later, on October 14th, 1962, the US found concrete evidence of USSR missiles located in Cuba. Consequently, President Kennedy ordered the establishment of the Executive Committee of the National Security Council. According to Fraser and Hipel (1982, 1984), the committee was tasked with formulating possible actions, which included:

- Aggressive options are not to be performed, which would result in an increased USSR missile power, the American early warning systems to be outmaneuvered, and damage credibility in American foreign promises. All these concerns could be mitigated by using the United Nations or the Organization of American States, or by a summit meeting with Khrushchev as a means for diplomatic pressure on the USSR to withdraw its missiles from Cuba and avoid an escalation to an all-out nuclear war.
- Conduct an air strike, which would destroy the bases that hold the missiles. This action will quite possibly require an inland invasion as a follow-up.
- Enforce a blockade by the American navy which would cut off all military supplies to Cuba.

(Fraser & Hipel, 1982, 1984)

Meanwhile, the USSR had three possible options in the dispute:

- Keep the missiles in Cuba
- Withdraw the missiles from Cuba
- Escalate the dispute by considering one of the following actions:
 - Attack the US navy ships
 - Launch missiles on American inland targets from Cuba
 - Launch an Inter-Continental Ballistic Missile attack on the US.
 - Attack West Berlin

(Fraser & Hipel, 1982, 1984; Hipel, 2011)

Historically, the US imposed a strategic military blockade on Cuba, and the USSR withdrew its missiles from Cuba (Fraser & Hipel, 1982, 1984).

6.2.1 The Conflict Model

Essentially all the key inputs were the same, as shown in the study published by Fraser and Hipel in 1982. The point in time considered for the conflict is October 17th, 1962. The relevant DMs in the conflict were the US and USSR, and Cuba was neglected since it had no independent action available at this time. Table 6.11 shows the option form of the Cuban Missile Crisis conflict. The preference ranking for the DMs was obtained from the same 1982 study published by Fraser and Hipel, which are explained in Tables 6.12, and 6.13 for the US and USSR respectively.

Table 6.11 Option form of the Cuban missile crisis conflict

DM	#	Ordered	1	2	3	4	5	6	7	8	9	10	11	12
US	1	Air Strike	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
	2	Blockade	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
USSR	3	Withdraw	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y

Table 6.12 Preference ranking of the US in the Cuban missile crisis conflict

DM	#	Options	Strategies											
US	1	Air Strike	N	N	Y	Y	N	Y	Y	N	Y	Y	N	N
	2	Blockade	N	Y	N	Y	Y	N	Y	N	Y	N	Y	N
USSR	3	Withdraw	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Preference (Ordered)			5	7	6	8	3	2	4	1	12	10	11	9

Table 6.13 Preference ranking of the USSR in the Cuban missile crisis conflict

DM	#	Options	Strategies											
US	1	Air Strike	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N
	2	Blockade	N	N	Y	Y	N	N	Y	Y	Y	N	Y	N
USSR	3	Withdraw	N	Y	Y	N	Y	N	Y	N	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Preference (Ordered)			1	5	7	3	6	2	8	4	12	10	11	9

6.2.2 Stability Analysis

Similar to the stability analysis of the previous conflicts shown in this study, GMCR+ (Kinsara et al., 2015b) was used to carry out the stability analysis of the conflict model. The individual stabilities are shown in Table 6.14 for the US, whereas Table 6.15 shows the individual stability of the USSR.

Table 6.14 Individual stability analysis of the Cuban missile crisis conflict with respect to the US

DM	#	Ordered	1	2	3	4	5	6	7	8	9	10	11	12
US	1	Air Strike	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
	2	Blockade	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
USSR	3	Withdraw	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	-	-	✓	-	✓	-	-	-	-	-	-	✓
		SEQ	-	-	✓	-	✓	-	✓	-	-	-	-	✓
		SMR	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
		GMR	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓

Table 6.15 Individual stability analysis of the Cuban missile crisis Conflict with respect to the USSR

DM	#	Ordered	1	2	3	4	5	6	7	8	9	10	11	12
US	1	Air Strike	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
	2	Blockade	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
USSR	3	Withdraw	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	✓	-	-	-	-	✓	✓	✓	-	-	-	-
		SEQ	✓	-	-	-	✓	✓	✓	✓	-	-	-	-
		SMR	✓	✓	✓	-	✓	✓	✓	✓	-	-	-	-
		GMR	✓	✓	✓	-	✓	✓	✓	✓	-	-	-	-

The equilibrium states are shown in Table 6.16, wherein States 5 and 7 are considered strong equilibrium states because the states are equilibria under SEQ stability. However,

States 1, 2, 3, 6, and 8 are all weak equilibria since they are considered as equilibria under SMR and GMR only. Historically, State 7 was the actual resolution in this dispute, where the US chose to impose a blockade on all military shipments to Cuba, and, in return, the USSR withdrew its missiles from Cuba.

Table 6.16 Stability analysis of the Cuban missile crisis conflict showing the equilibrium states

DM	#	Ordered	1	2	3	4	5	6	7	8	9	10	11	12
US	1	Air Strike	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
	2	Blockade	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
USSR	3	Withdraw	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	4	Escalate	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts	Nash		-	-	-	-	-	-	-	-	-	-	-	-
	SEQ		-	-	-	-	✓	-	✓	-	-	-	-	-
	SMR		✓	✓	✓	-	✓	✓	✓	✓	-	-	-	-
	GMR		✓	✓	✓	-	✓	✓	✓	✓	-	-	-	-

6.2.3 Strength of Equilibria

With the equilibrium states in the conflict model identified, one can calculate the strength of each equilibrium state using Equation 3.1. As mentioned earlier, States 1, 2, 3, 6, and 8 are equilibria under SMR and GMR only, meaning that each of these states accumulates 3 strength points. Meanwhile, States 5 and 7 are both SEQ, SMR, and GMR equilibria and thus accumulate 6 points each. The strength of equilibria computation is shown in Table 6.17. As previously explained, States 5 and 7 are strong equilibria and hence both have the

highest strength, whereas States 1, 2, 3, 6, and 8 have lower strength since they are considered weak equilibria.

Table 6.17 Strength of Equilibria calculation of the Cuban missile crisis conflict model

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_1$	0	0	1	1	3
$E_2 = S_2$	0	0	1	1	3
$E_3 = S_3$	0	0	1	1	3
$E_4 = S_5$	0	1	1	1	6
$E_5 = S_6$	0	0	1	1	3
$E_6 = S_7$	0	1	1	1	6
$E_7 = S_8$	0	0	1	1	3

6.2.4 Option Effectiveness

One can calculate the Option Effectiveness for all the options available in the conflict model once the strength of each equilibrium state has been computed Equation 3.2. The strength of the equilibria values shown in Table 6.17 are considered to calculate the Option Effectiveness of the Cuban Missile Crisis conflict model. Table 6.18 explains the option selection occurrences and the effectiveness of each option in the conflict.

Table 6.18 Option Effectiveness calculation of the Cuban Missile Crisis conflict model

	O_1	O_2	O_3	O_4	Strength of Equilibrium
$E_1 = S_1$	0	0	0	0	3
$E_2 = S_2$	1	0	0	0	3
$E_3 = S_3$	0	1	0	0	3
$E_4 = S_5$	0	0	1	0	6
$E_5 = S_6$	1	0	1	0	3
$E_6 = S_7$	0	1	1	0	6
$E_7 = S_8$	1	1	1	0	3
Option Effectiveness	9	12	18	0	

One can rank the options in terms of their importance based on the option effectiveness values achieved by each of the options (from most important to least important), starting with the option that has highest value of option effectiveness towards the option that has the lowest value. In case of the Cuban Missile Crisis conflict, Option 3, withdrawal of the missiles from Cuba by the USSR, is the option that achieved the highest option effectiveness value of 18, and can be considered the most important option. Option 3 is selected in four of the seven equilibrium states, and two of these states have strong equilibria. Also, Option 3 is the main objective of the US and secretly of the USSR as well, in order to avoid an all-out nuclear war. Option 3 was also part of the real-world resolution of the conflict, thus making it the most important option in the model and justifying its position as the option with the highest option effectiveness value in the conflict. Furthermore, Option 2, the enforcement of a blockade by the US, is ranked 2nd with respect to option importance and effectiveness, since it accumulated an option effectiveness value of 12. Is it considered that Option 3 is not

available without the selection of Option 2. The 3rd-ranked option is Option 1, launching an airstrike by the US, since it achieved a value of 9. Moreover, Option 4, escalation towards a nuclear war by the USSR, is ranked the lowest as it is not a part of any of the equilibrium states, as shown in Table 6.18. In fact, scenarios involving Option 4 are least preferred by both DMs, which justifies Option 4 having the least effectiveness value in the conflict model. The most effective option is withdrawal by the USSR, and next to it is the blockade option by the US.

6.3 The Garrison Diversion Unit

The Option Effectiveness approach has shown its capabilities in analyzing conflict models at the option level by its application in the previous mentioned case studies. However, applying the Option Effectiveness approach to a more complex conflict will strengthen the understanding of it and show its capabilities in investigating conflicts at the option level. Therefore, the Garrison Diversion Unit (GDU) dispute, which is considered a very complex conflict model (Fraser & Hipel, 1984), is used to demonstrate the Option Effectiveness procedure on a complex conflict model.

The GDU is a multipurpose water resource project which involves transferring water from the Missouri River to regions in central and eastern North Dakota located in the Hudson Bay drainage basin. Irrigation is one of the major benefits of water for the Americans, while some of the other benefits are the provision of municipal and industrial water supplies, increased employment, and wildlife and recreational areas (Fraser & Hipel, 1984).

The GDU dispute arose when the Canadians feared that substantial environmental harm and danger may result from the GDU project due to polluted irrigation water flowing into Canada through the Souris and Red Rivers. Also, concerns of American environmentalists that the environmental damage in the US had been underestimated were another cause of the conflict. International Joint Commission (IJC), an entity that deals with political disputes between the US and Canada which are related to water boundaries (Fraser & Hipel, 1984).

6.3.1 The Conflict Model

The point in time considered for the conflict model is April 1976 (Hipel & Fraser, 1980), and the parties with interests in the conflict involve:

- United States Support for Garrison (US Support): a group of entities that expressed support for the GDU project, which include: the Bureau of Reclamation of the US Department of the Interior, which gave the greatest support; the Oversight Management Group within the US Department of the Interior; The Garrison Diversion Conservancy District, which is a highly-funded politically strong organization; the State of North Dakota; the Garrison Diversion Irrigation Council; the National Park Service; and the North Dakota State Game and Fish Department (Fraser & Hipel, 1984).
- United States Opposition to Garrison (US Opposition): consisting mainly of environmental activists and organizations. The participating environmental organizations are the National Audubon Society, the Environmental Protection

Agency, the Bureau of Sports Fisheries and Wildlife, and the President's Council on Environmental Quality (Fraser & Hipel, 1984).

- Canadian Opposition to Garrison (Canadian Opposition): many Canadian organizations have expressed their opposition to the GDU project, and include the Canadian Federal Government, the Manitoba Provincial Government, Environment Canada, the Manitoba Environmental Council, the Prairie Environmental Defense League, the Manitoba Wildlife Federation, the Manitoba Ministry of Mines, Resources, and Environmental Management, and other industries, municipalities, and activists (Fraser & Hipel, 1984).
- International Joint Commission: the commission was established within Article VI of the "treaty Between the United States and Great Britain Relating to Boundary Waters and Questions Arising Between the United States and Canada" in 1909 (Fraser & Hipel, 1984).

The conflict model considers several possible options for the DMs involved; these options are summarized in Table 6.19, which is based on a table from (Fraser & Hipel, 1984). The conflict model has a possible 512 states of which 489 are deemed to be infeasible based on the elimination criteria mentioned in the book. The general option form including 23 feasible states is shown in Table 6.20. The preference rankings for each DM are listed in Table 6.21, from "most preferred" on the left to "least preferred" on the right.

Table 6.19 The possible options available for the decision makers in the Garrison Diversion Unit conflict (Fraser & Hipel, 1984)

DMs	#	Options
US Support	1	Continue with the completion of the full GDU project
	2	Modify the GDU project to reduce Canadian environmental impacts
	3	Modify the GDU project to please American environmentalists
US Opposition	4	Pursue legal action based on environmental legislation
Canadian Opposition	5	Pursue legal action based on the Boundary Treaty of 1909
IJC	6	Back the accomplishment of the full GDU project
	7	Back the accomplishment of a modified GDU to reduce Canadian environmental impacts
	8	Back the cancellation of the GDU project with an exception for the Lonetree Reservoir project
	9	Back the complete cancellation of the GDU project

Table 6.20 Option form of the Garrison Diversion Unit conflict

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
		States (Decimal)	34	36	41	42	50	52	57	58	66	68	74	82	84	89	90	146	148	153	154	274	276	281	282
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y

Table 6.21 Preference ranking of US Support, US Opposition, Canadian Opposition, and IJC in the Garrison Diversion Unit conflict

Preference Ranking																							
(States are ranked from most preferred to the left to least preferred to the right)																							
US Support	3	7	[1	2]	4	[5	6]	8	9	12	11	15	10	13	14	17	16	18	19	21	20	22	23
US Opposition	[2	6	10	13	17	21]	[19	23]	15	11	8	4	22	18	14	7	3	20	16	12	9	5	1
Canadian Opposition	23	[20	21]	19	[16	17]	11	[9	10]	15	[12	13]	2	4	1	8	[5	6]	22	18	14	3	7
IJC	[1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23]

6.3.2 Stability Analysis

The stability analysis of the GDU conflict model was done using GMCR+ (Kinsara et al., 2015b). Tables 6.22, 6.23, 6.24, and 6.25 show the results of the individual stability analyses for US Support, US Opposition, Canadian Opposition, and IJC respectively. The states found to be stable under a given solution concept, such as Nash, SEQ, SMR, and GMR, for all the DMs are considered equilibria under those solution concepts. Table 6.26 shows the equilibrium states in the conflict model for all the solution concepts. The investigation revealed that States 2, 3, 11, 17, 18, 21, and 22 are strong equilibrium states, since each of these states is an equilibrium under the Nash solution concept; hence, they are also considered as equilibria under the remaining solution concepts. Moreover, States 8, 13, 14, 15, and 19 are weak equilibria, since they are only found as equilibrium states under the SMR and GMR solution concepts.

Table 6.22 Individual stability analysis of the Garrison Diversion Unit conflict with respect to US Support

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	✓	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓	-	-	✓	-	✓	✓	-	-	✓	✓	-	
		SEQ	✓	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓	-	-	✓	-	✓	✓	-	-	✓	✓	-	
		SMR	✓	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
		GMR	✓	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-

Table 6.23 Individual stability analysis of the Garrison Diversion Unit conflict with respect to US Opposition

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	✓
		SEQ	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	✓
		SMR	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	✓
		GMR	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	✓

Table 6.24 Individual stability analysis of the Garrison Diversion Unit conflict with respect to Canadian Opposition

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	✓	✓	✓	✓	-	-	-	-	✓	✓	✓	-	-	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	
		SEQ	✓	✓	✓	✓	-	-	-	✓	✓	✓	✓	-	-	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	
		SMR	✓	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		GMR	✓	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 6.25 Individual stability analysis of the Garrison Diversion Unit conflict with respect to IJC

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y
Solution concepts		Nash	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		SEQ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		SMR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		GMR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 6.26 Stability analysis of the Garrison Diversion Unit conflict showing the equilibrium states

DM	#	States (Ordered)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
US Support	1	Full	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
	2	Reduced	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y
	3	Appease	N	Y	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	N	N	Y	N	N
US Opposition	4	Legal	N	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
Canadian Opposition	5	Treaty	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IJC	6	Full	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	7	Reduced	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	8	Lonetree	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
	9	Suspended	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Solution concepts		Nash	-	✓	✓	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	✓	-	-	✓	✓	-
		SEQ	-	✓	✓	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	✓	-	-	✓	✓	-
		SMR	-	✓	✓	-	-	-	-	✓	-	-	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-
		GMR	-	✓	✓	-	-	-	-	✓	-	-	✓	-	✓	✓	✓	-	✓	✓	✓	-	✓	✓	-

6.3.3 Strength of Equilibria

The calculation of the strength of each equilibrium state was carried out using Equation 3.1. Since States 2, 3, 11, 17, 18, 21, and 22 have been found to equilibria under Nash, SEQ, SMR, and GMR solution concept, they accumulate 10 strength points each. As for the remaining equilibrium states, States 8, 13, 14, 15, and 19, have 3 points each due to the fact that they are equilibria under SMR and GMR solution concepts only.

Table 6.27 Strength of Equilibria calculation of the Garrison Diversion Unit conflict model

Equilibrium	Equilibrium representation using the solution concepts				Strength of Equilibrium
	Nash (4)	SEQ (3)	SMR (2)	GMR (1)	
$E_1 = S_2$	1	1	1	1	10
$E_2 = S_3$	1	1	1	1	10
$E_3 = S_8$	0	0	1	1	3
$E_4 = S_{11}$	1	1	1	1	10
$E_5 = S_{13}$	0	0	1	1	3
$E_6 = S_{14}$	0	0	1	1	3
$E_7 = S_{15}$	0	0	1	1	3
$E_8 = S_{17}$	1	1	1	1	10
$E_9 = S_{18}$	1	1	1	1	10
$E_{10} = S_{19}$	0	0	1	1	3
$E_{11} = S_{21}$	1	1	1	1	10
$E_{12} = S_{22}$	1	1	1	1	10

6.3.4 Option Effectiveness

The Option Effectiveness computation can be carried out using Equation 3.2 for all the options available in the conflict model for the purpose of ranking them with respect to their

importance towards contributing to the resolution of the conflict. As mentioned earlier, the strength of each equilibrium state serves as the basis for calculating the Option Effectiveness. Table 6.28 shows the option selection of each option in the columns next to each equilibrium state, mentioned in the left side of the table, whereas the strength of the equilibrium state is shown in the last column to the right. The last row in the table computes the Option Effectiveness for the options available in the conflict model.

The options can be ranked according to their importance in the conflict model. Table 6.29 shows the ranking of the options with respect to their importance in the conflict from “most important” on the left to “least important” on the right. Options listed in the same bracket are tied in terms of their importance, since they have the same option effectiveness value. Option 5, pursuing legal action by the Canadian Opposition, is ranked as the most important option. One can argue that Option 5 is the cause of the conflict, an argument that justifies Option 5 having the highest importance. On the other hand, Option 4, pursuing legal action by US Opposition, which is ranked 2nd in Table 6.29, can be seen as a secondary cause of the conflict, so its 2nd rank in the importance aspect can be defended.

Historically, the conflict ends in State 17, or 148 in decimal numbering, where the US Support appeases the US Opposition, and in return, the US Opposition does not pursue legal action. Meanwhile, the Canadian Opposition pursues its legal action based on the Boundary Treaty of 1909 and IJC recommends the suspension of the whole GDU project with an exception for the Lonetree Reservoir.

Option 1, completion of the full GDU project by US Support, and Option 3, pleasing the US Opposition by US Support, are tied at 3rd in importance, meaning that they have a similar contribution towards the equilibrium states of the conflict. Similarly, Option 6, backing the full completion of the GDU project by IJC, and Option 8, backing the suspension of the whole GDU project except the Lonetree Reservoir by the IJC, are both ranked 4th and have a similar contribution to the equilibria of the conflict model. Also, Option 2, modify the GDU project to reduce Canadian environmental impacts by the US Support, and Option 7, backing the reduced scope of the GDU project by IJC to reduce Canadian environmental impacts, are both ranked as the options with least importance.

For the Canadian Opposition to reach its objective of reducing the environmental dangers and impacts that could be caused by the GDU project, it has to make Option 2 more important for the US opposition. But it is currently their least important option. The conflict ending in State 17 justifies the option importance ranking. This state has Option 1 as selected, which is the most important option in the whole dispute; Option 3 is chosen, which is the most important option for US Support; and Option 8 as exercised by IJC, which is their most important option. Option 4, which is ranked 2nd in option importance, is not selected because US Support has decided to appease US Opposition, and in return, US Opposition would not pursue any legal action.

Table 6.28 Option Effectiveness calculation of the Garrison Diversion Unit conflict model

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	O_9	Strength of Equilibrium
$E_1 = S_2$	0	0	1	0	0	1	0	0	0	10
$E_2 = S_3$	1	0	0	1	0	1	0	0	0	10
$E_3 = S_8$	0	1	0	1	1	1	0	0	0	3
$E_4 = S_{11}$	0	1	0	1	0	0	1	0	0	10
$E_5 = S_{13}$	0	0	1	0	1	0	1	0	0	3
$E_6 = S_{14}$	1	0	0	1	1	0	1	0	0	3
$E_7 = S_{15}$	0	1	0	1	1	0	1	0	0	3
$E_8 = S_{17}$	0	0	1	0	1	0	0	1	0	10
$E_9 = S_{18}$	1	0	0	1	1	0	0	1	0	10
$E_{10} = S_{19}$	0	1	0	1	1	0	0	1	0	3
$E_{11} = S_{21}$	0	0	1	0	1	0	0	0	1	10
$E_{12} = S_{22}$	1	0	0	1	1	0	0	0	1	10
Option Effectiveness	33	19	33	52	55	23	19	23	20	

Table 6.29 Option importance ranking in the Garrison Diversion Unit conflict model

	O_5	O_4	[O_1	O_3]	[O_6	O_8]	O_9	[O_2	O_7]
Action Description	Treaty	Legal	Full	Appease	Full	Lonetree	Suspended	Reduced	Reduced
Option Effectiveness	55	52	33	33	23	23	20	19	19
DM	Canadian Opposition	US Opposition	US Support	US Support	IJC	IJC	IJC	US Support	IJC

6.4 Summary

The Option Effectiveness approach has been applied to three real-world conflict models and has demonstrated its capacity to illuminate conflicts at the option level. The approach has

shown promising conclusions, and seems to allow a better understanding for analysts about options and their importance in a conflict.

The approach has shown that it can identify options that are the root cause of conflicts and usually have the highest option effectiveness values. Meanwhile, options that are less likely to be part of any resolution tend to have very low option effectiveness values, indicating their insignificance in the conflict model. The Option Effectiveness has been able to predict which option would be a better counter-move among a set of options. In many cases, an option that can be used as an effective counter-move for the opposing DM is ranked 2nd among all the options. Furthermore, options selected in the real-world resolution of a dispute tend to be ranked higher than other options in the Option Effectiveness ranking order. The information revealed by this approach allows DMs clarity about the options in-hand and may focus their efforts to resolve conflicts in their favor.

Chapter 7

Conclusions and Future Work

The investigation of the economic conflict between China and the US was carried out by using the GMCR methodology. The results indicate that China is well on its way to overcome the US as the world's largest economic superpower. In fact, the study revealed that establishing the AIIB by China was the root cause of the conflict, while forcing China to accept US terms was the best counter-move in the second phase of the dispute. The analysis of the third phase of the conflict has shown that China is strengthening its economic position by implementing the RCEP agreement.

The newly introduced method, Option Effectiveness, has shown satisfactory results and allowed further understanding when applied to the real-world conflict models of the Elmira Groundwater Contamination conflict, the Cuban Missile Crisis conflict, and the Garrison Diversion Unit conflict. In fact, the approach has helped in achieving a strategic understanding at the option level of the conflicts. The approach has illustrated its capability of ranking the options with respect to their importance. Option Effectiveness can help DMs in a dispute in turning the tides of the conflict in their favor.

The classification of states by a pattern which can be used in categorizing states into groups was proposed by Fang et al. (2003a, 2003b). Automation of the proposed classification can be handled by the Option Effectiveness approach, and the novel approach can classify the equilibrium states through the importance of the options. For instance, a category can consist

of the states in which the most effective option is chosen, whereas the states where the least effective option is selected can form another category. To sum up, the Option Effectiveness procedure is able to automate the initial categorization process for the equilibrium states.

7.1 Future Work

The preferences of the DMs involved in a conflict play an essential role in constructing a conflict model using the GMCR methodology constructs. The stability analysis of the conflict model is entirely dependent on these preferences, as it is the only way to determine the UIs for a DM in a conflict model. Therefore, an extension of the Option Effectiveness approach can be modeled which considers the preferences of the DMs in the computation of option effectiveness. A preliminary approach is mentioned in Appendix A which considers the preferences of DMs for the equilibrium states of the conflict model and includes it in the option effectiveness computations. Further research can be directed in this area to optimize the approach and apply it to real-world conflict models for evaluation.

Bibliography

- Ablow, G. (2016, September 1). Why is Obama Pushing the TPP?: Moyers & Company.
Retrieved December 12, 2017, from: <http://billmoyers.com/story/obamas-push-tpp/>
- About AIIB Overview - AIIB. (n.d.). *Asian Infrastructure Investment Bank*. Retrieved
December 12, 2017, from: <https://www.aiib.org/en/about-aiib/index.html>
- About the IMF. (n.d.). *International Monetary Fund*. Retrieved May 2, 2018, from:
<http://www.imf.org/en/About>
- Abramovitz, M., & David, P. A. (1973). Reinterpreting economic growth: parables and
realities. *The American Economic Review*, 63(2), 428-439.
- Ahmed, K. (2011, November 19). Jim O'Neill: China could overtake US economy by 2027.
The Telegraph. Retrieved December 12, 2017, from:
<http://www.telegraph.co.uk/finance/economics/8901828/Jim-ONeill-China-could-overtake-US-economy-by-2027.html>
- Alhindi, T. J., Hipel, K. W., & Kilgour, D. M. (2017a). China, USA, Japan and the
Asian Infrastructure Investment Bank. (M. Schoop, & D. M. Kilgour, Eds.)
*extended abstract published in the Proceedings of the 17th International
Conference on Group Decision and Negotiation*, 167-173.
- Alhindi, T. J., Hipel, K. W., & Kilgour, D. M. (2017b). The Conflict over the Asian
Infrastructure Investment Bank involving China, USA and Japan. *Invited paper
published in the special session on Conflict Resolution in the Proceedings of the*

2017 IEEE International Conference on Systems, Man, and Cybernetics, 3584-3589. © 2017 IEEE. Reprinted, with permission, from Alhindi, T. J., Hipel, K. W., & Kilgour, D. M., "The Conflict over the Asian Infrastructure Investment Bank involving China, USA and Japan", 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Oct. 2017.

Alhindi, T. J., Hipel, K. W., & Kilgour, D. M. (2018a). A Measure for Option Effectiveness in the Graph Model for Conflict Resolution. *Extended abstract to be published in the Proceedings of the 18th International Conference on Group Decision and Negotiation.*

Alhindi, T. J., Hipel, K. W., & Kilgour, D. M. (2018b). The conflict over global trade agreements between China and the United States. Unpublished Manuscript. Dept. of Systems Design Engineering, University of Waterloo, Waterloo, ON, Canada.

Alhindi, T. J., Kilgour, D. M., & Hipel, K. W. (2018c). Option Effectiveness in Conflict Resolution. *Invited paper to be published in the special session on Conflict Resolution in the Proceedings of the 2018 IEEE International Conference on Systems, Man, and Cybernetics.* © 2018 IEEE. Reprinted, with permission, from Alhindi, T. J., Kilgour, D. M., & Hipel, K. W., "Option Effectiveness in Conflict Resolution ", 2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Oct. 2018.

- Aljefri, Y. M., Fang, L., & Hipel, K. W. (2014). Modeling Misperception of Options and Preferences in the Graph Model for Conflict Resolution. Proceedings of the *IEEE International Conference on Systems, Man, and Cybernetics*, (pp. 1592-1597). San Diego, CA, USA.
- Aljefri, Y., Bashar, M., Fang, L., & Hipel, K. W. (2017). First-Level Hypergame for Investigating Misperception in Conflicts. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, DOI: 10.1109/TSMC.2017.2690619
- Asian Development Bank. (2015). *ANNUAL REPORT 2015*. Retrieved December 12, 2017, from: <https://www.adb.org/sites/default/files/institutional-document/218696/oi-appendix1.pdf>
- BBC. (n.d.). BBC - History - Mao Zedong (1893-1976). Retrieved May 9, 2018, from: http://www.bbc.co.uk/history/historic_figures/mao_zedong.shtml
- Bernstein, R. (2015). *China 1945: Mao's Revolution and America's Fateful Choice*. Vintage.
- Breuninger, K., & Tausche, K. (2018, March 22). Trump slaps China with tariffs on up to \$60 billion in imports. *CNBC*. Retrieved April 30, 2018, from: <https://www.cnbc.com/2018/03/22/trump-moves-to-slap-china-with-50-billion-in-tariffs-over-intellectual-property-theft.html>
- Brinkley, J. (2017, January 24). Trump Hands China A Gift In Dumping Trans-Pacific Partnership. *Forbes*. Retrieved December 12, 2017, from:

<https://www.forbes.com/sites/johnbrinkley/2017/01/24/trump-dumps-trans-pacific-partnership-sad/#6fd8dd2c75dc>

Cheng, Y. (2018). Public Opinions on the Belt and Road Initiative: A Cross-Cultural Study. In Y. Cheng, L. Song, & L. Huang (Eds.), *The Belt & Road Initiative in the Global Arena* (pp. 3-15). Palgrave Macmillan.

China's One Belt, One Road: Will it reshape global trade?. (2016, July).

McKinsey & Company. Retrieved May 2, 2018, from:

<https://www.mckinsey.com/featured-insights/china/chinas-one-belt-one-road-will-it-reshape-global-trade>

Chossudovsky, M. (2018). World Bank. In *Encyclopædia Britannica*. Retrieved May 2, 2018, from: <https://www.britannica.com/topic/World-Bank>

Donnan, S. (2015, September 27). White House declares truce with China over AIIB.

Financial Times. Retrieved December 2016, from:

<https://www.ft.com/content/23c51438-64ca-11e5-a28b-50226830d644>

Efthymiou, P. (2013, February 12). The Emergence Of The United States As A Global Power. *The Risky Shift.com*. Retrieved May 2, 2018, from:

http://theriskyshift.com/2013/02/the-emergence-of-the-united-states-as-a-global-power/#_ftn1

- Evans, P. (2017, January 23). Trump pulls U.S. out of TPP, will renegotiate NAFTA 'at the appropriate time'. *CBC*. Retrieved December 12, 2017, from:
<http://www.cbc.ca/news/business/donald-trump-trade-nafta-1.3947989>
- Fang, L., Hipel, K. W., & Kilgour, D. M. (1989). Conflict models in graph form: Solution concepts and their interrelationships. *European Journal of Operational Research*, *41*, 86-100.
- Fang, L., Hipel, K. W., & Kilgour, D. M. (1993). *Interactive Decision Making: The Graph Model for Conflict Resolution*. New York: Wiley.
- Fang, L., Hipel, K. W., Kilgour, D. M., & Peng, X. (2003a). A Decision Support System for Interactive Decision Making, Part 1: Model Formulation. *IEEE Transactions on Systems, Man and Cybernetics, Part C: Applications and Reviews*, *33*(1), 42-55.
- Fang, L., Hipel, K. W., Kilgour, D. M., & Peng, X. (2003b). A Decision Support System for Interactive Decision Making, Part 2: Analysis and Output Interpretation. *IEEE Transactions on Systems, Man and Cybernetics, Part C: Applications and Reviews*, *33*(1), 56-66.
- France, Germany, Italy to Join China-led \$50bn Infrastructure Bank. (2015, March 19). *RT*. Retrieved December 12, 2017, from: <https://www.rt.com/business/241365-china-bank-eu-usa/>
- Fraser, N. M., & Hipel, K. W. (1979). Solving Complex Conflicts. *IEEE Transactions on Systems, Man, and Cybernetics*, *9*(12), 805-816.

- Fraser, N. M., & Hipel, K. W. (1982). Dynamic Modelling of the Cuban Missile Crisis. *Conflict Management and Peace Science*, 6(2), 1-18.
- Fraser, N. M., & Hipel, K. W. (1984). *Conflict Analysis: Models and Resolutions* (Vol. 11). New York, NY, USA: North-Holland.
- Goh, B. (2014, November 5). Three major nations absent as China launches World Bank rival in Asia. *Reuters*. Retrieved December 12, 2017, from: <http://www.reuters.com/article/us-china-aiib-idUSKCN0ID08U20141105>
- Gott, R. (2011). *Britain's Empire: Resistance, Repression and Revolt*. Verso Books.
- Gwin, C. (1997). *The World Bank: its First Half Century* (Vol. 2). (D. Kapur, J. P. Lewis, & R. C. Webb, Eds.)
- Hipel, K. W. (2011). A Systems Engineering Approach to Conflict Resolution in Command and Control. *The International C2 Journal*, 5(1), 1-56
- Hipel, K. W., & Fraser, N. M. (1980). Metagame Analysis of the Garrison Conflict. *Water Resources Research*, 16(4), 629-637.
- Hipel, K. W., & Walker, S. (2011). Conflict Analysis in Environmental Management. *Environmetrics*, 22(3), 279-293.
- Hipel, K. W., Kilgour, D. M., Fang, L., & Peng, X. (1997). The Decision Support System GMCR in Environmental Conflict Management. *Applied Mathematics and Computation*, 83(2,3), 117-152.

- Hipel, K. W., Kilgour, D. M., Fang, L., & Peng, X. (1999). The Decision Support System GMCR II in Negotiations over Groundwater Contamination. *Invited paper published in the special session on Conflict and Risk Analysis in Regional Management in the Proceedings of the 1999 IEEE International Conference on Systems, Man and Cybernetics held at the Tokyo International Forum, V942-V948.*
- Hirst, T. (2015, July 30). A brief history of China's economic growth. *World Economic Forum*. Retrieved May 1, 2018, from:
<https://www.weforum.org/agenda/2015/07/brief-history-of-china-economic-growth/>
- Hobson, J. M. (2004). *The Eastern Origins of Western Civilization*. Cambridge, UK: Cambridge University Press.
- Howard, N. (1971). *Paradoxes of Rationality: Theory of Metagames and Political Behavior*. Cambridge, MA, USA: MIT Press.
- Huang, C. (2015, April 15). 57 nations approved as founder members of China-led AIIB. *South China Morning Post*. Retrieved December 12, 2017, from:
<http://www.scmp.com/news/china/diplomacy-defence/article/1766970/57-nations-approved-founder-members-china-led-aiib>
- Husna, Rida. (2018, May 17). China GDP Annual Growth Rate. *Trading Economics*. Retrieved May 2, 2018 from: <https://tradingeconomics.com/china/gdp-growth-annual>

IMF Data. (n.d.). *International Monetary Fund*. Retrieved from:

<http://data.imf.org/?sk=388DFA60-1D26-4ADE-B505-A05A558D9A42>

IMF Members' Quotas and Voting Power, and IMF Board of Governors. (2018).

International Monetary Fund. Retrieved May 17, 2018, from:

<https://www.imf.org/external/np/sec/memdir/members.aspx#1>

Jacques, M. (2012). *When China rules the world : The end of the western world and the birth of a new global order*. New York: Penguin Books.

Jin, K. (2017, May 21). What Belt and Road mean for the world. *Chinadaily.com.cn*.

Retrieved December 12, 2017, from: http://europe.chinadaily.com.cn/opinion/2017-04/21/content_29020824.htm

Kamrany, N. M., & Jiang, F. (2015, February 2). China's Rise to Global Economic Superpower. *HuffPost*. Retrieved April 24, 2018, from:

https://www.huffingtonpost.com/nake-m-kamrany/chinas-rise-to-global-eco_b_6544924.html

Kilgour, D. M., & Hipel, K. W. (2005). The Graph Model for Conflict Resolution: Past, Present, and Future. *Group Decision and Negotiation*, 14(6), 441-460.

Kilgour, D. M., & Hipel, K. W. (2010). Conflict Analysis Methods: The Graph Model for Conflict Resolution. In D. M. Kilgour, & C. Eden (Eds.), *Handbook of Group Decision and Negotiation*. Dordrecht, Netherlands: Springer.

- Kilgour, D. M., Hipel, K. W., & Fang, L. (1987). The Graph Model for Conflicts. *Automatica*, 23(1), 41-55.
- Kinsara, R., Kilgour, D. M., & Hipel, K. W. (2015a). Inverse Approach to the Graph Model for Conflict Resolution. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 45(5), 734-742. DOI: 10.1109/TSMC.2014.2376473
- Kinsara, R. A., Petersons, O., Hipel, K. W., & Kilgour, D. M. (2015b). Advanced Decision Support for the Graph Model for Conflict Resolution. *Journal of Decision Systems*, 24(2), 117-145.
- MacMillan, M. (2002). *Paris 1919 : Six Months That Changed the World* (1st U.S. ed.). New York: Random House.
- Matbouli, Y., Kilgour, D. M., & Hipel, K. W. (2015). Robustness of Equilibria in the Graph Model for Conflict Resolution. *Journal of Systems Science and Systems Engineering*, 24(4), 450-465.
- Mathieson, R. (2017, November 14). Agreeing on RCEP — China’s favorite trade deal — set to drag into 2018. *The Japan Times*. Retrieved May 2, 2018, from: <https://www.japantimes.co.jp/news/2017/11/14/business/agreeing-rcep-chinas-favorite-trade-deal-set-drag-2018/#.WulBnogvwuU>
- McDougall, W. A. (1997). *Promised Land, Crusader State: The American Encounter with the World since 1776*. New York: Houghton Mifflin.

- Mead, W. R. (2002). *Special Providence: American Foreign Policy and How It Changed the World*. New York: Routledge.
- Mie, A. (2016, September 22). AIIB holdout Japan risks missing out on the infrastructure contracts it seeks. *The Japan Times*. Retrieved December 12, 2017, from: <http://www.japantimes.co.jp/news/2016/09/22/national/politics-diplomacy/aiib-holdout-japan-risks-missing-infrastructure-contracts-seeks/#.WDHmS-YrIuU>
- Mitrovic, D. (2018). China's Belt and Road Initiative: Connecting and Transforming Initiative. In Y. Cheng, L. Song, & L. Huang (Eds.), *The Belt and Road Initiative in the Global Arena* (pp. 17-34). Palgrave Macmillan.
- Nash, J. F. (1950). Equilibrium Points in N-Person Games. *Proceedings of the National Academy of Sciences of the United States of America*, 36(1), 48-49.
- Nash, J. (1951). Non-Cooperative Games. *Annals of Mathematics*, 54(2), 286-295.
- Perlez, J. (2015, December 4). China Creates a World Bank of Its Own, and the U.S. Balks. *The New York Times*. Retrieved January 6, 2018, from: http://www.nytimes.com/2015/12/05/business/international/china-creates-an-asian-bank-as-the-us-stands-alooft.html?_r=0
- Petras, J. (2012, March 7). China: Rise, Fall and Re-Emergence as a Global Power. *Global Research*. Retrieved May 1, 2018, from: <https://www.globalresearch.ca/china-rise-fall-and-re-emergence-as-a-global-power/29644>

Phillips, T. (2017, May 12). The \$900bn question: What is the Belt and Road initiative?

The Guardian. Retrieved May 2, 2018, from:

<https://www.theguardian.com/world/2017/may/12/the-900bn-question-what-is-the-belt-and-road-initiative>

Picardo, E. (2018, April 5). 10 Countries With The Biggest Forex Reserves. *Investopedia*.

Retrieved May 2, 2018, from:

<https://www.investopedia.com/articles/investing/033115/10-countries-biggest-forex-reserves.asp>

Regional Comprehensive Economic Partnership. (n.d.). *Australian Government*:

Department of Foreign Affairs and Trade. Retrieved December 12, 2017, from:

<http://dfat.gov.au/trade/agreements/rcep/pages/regional-comprehensive-economic-partnership.aspx>

Regional Comprehensive Economic Partnership (RCEP). (2016, October 3). *Association of*

Southeast Asian Nations. Retrieved December 12, 2017, from:

http://asean.org/?static_post=rcep-regional-comprehensive-economic-partnership

Schulzinger, R. D. (2008). *U.S. Diplomacy since 1900* (6th Ed.). Oxford: Oxford

University Press.

Sink, J., Olorunnipa, T., & Curran, E. (2017, January 24). China Eager to Fill Political

Vacuum Created by Trump's TPP Withdrawal. *Bloomberg*. Retrieved December 12,

2017, from: <https://www.bloomberg.com/politics/articles/2017-01-23/trump-s-withdrawal-from-asia-trade-deal-viewed-as-boon-for-china>

Stevenson, D. (2004). *1914-1918: the history of the First World War*. London, UK: Penguin.

Thomas, K., & Wiseman, P. (2018, March 23). Trump orders huge tariffs on China, raises trade war worries. *AP News*. Retrieved April 30, 2018, from: <https://apnews.com/73e5e5aa7be2408892e9904d642d2137>

Timeline: U.S. Relations With China 1949 - 2018. (n.d.). *Council on Foreign Relations*. Retrieved April 30, 2018, from: <https://www.cfr.org/timeline/us-relations-china>

Toussaint, E. (2014a, September 1). Domination of the United States on the World Bank. *Committee for the Abolition of Illegitimate Debt*. Retrieved May 2, 2018, from: <http://www.cadtm.org/Domination-of-the-United-States-on>

Toussaint, E. (2014b, August 5). Why the Marshall Plan? *Committee for the Abolition of Illegitimate Debt*. Retrieved May 2, 2018, from: <http://www.cadtm.org/Why-the-Marshall-Plan>

Wan, M. (2016). *The Asian Infrastructure Investment Bank: The Construction of Power and the Struggle for the East Asian International Order*. New York: Palgrave Macmillan.

Wang, X. (2016, November 17). Good News For China? No TPP For The U.S., And Now Vietnam. *Forbes*. Retrieved December 12, 2017, from:

<http://www.forbes.com/sites/xiangwang/2016/11/17/good-news-for-china-no-tpa-for-the-u-s-and-now-vietnam/#157cbb343dc8>

Weisberger, B. A., Rollins, R. C., Robinson, E. E., Lewis, P. F., Freidel, F., Gopnik, A., ...Zelinsky, W. (2018). United States. In *Encyclopædia Britannica*. Retrieved May 2, 2018, from: <https://www.britannica.com/place/United-States/World-War-II>

What We Do. (n.d.). *World Bank*. Retrieved May 2, 2018, from:

<http://www.worldbank.org/en/what-we-do>

Who We Are. (n.d.). *Asian Development Bank*. Retrieved December 12, 2017, from:

<https://www.adb.org/about/main>

Wong, C. (2017, January 25). China to push forward own trade vision after Trump withdraws from Pacific deal. *South China Morning Post*. Retrieved December 12, 2017, from: [http://www.scmp.com/news/china/diplomacy-](http://www.scmp.com/news/china/diplomacy-defence/article/2064956/chinese-analysts-cautious-over-whether-us-withdrawal)

[defence/article/2064956/chinese-analysts-cautious-over-whether-us-withdrawal](http://www.scmp.com/news/china/diplomacy-defence/article/2064956/chinese-analysts-cautious-over-whether-us-withdrawal)

Wong, S.-L. (2016, January 17). China launches new AIIB development bank as power balance shifts. *Reuters*. Retrieved December 12, 2017, from:

<http://www.reuters.com/article/us-asia-aiib-investment-idUSKCN0UU03Y>

World Bank. (2018). *International Bank for Reconstruction and Development*

Subscriptions and Voting Power of Member Countries. Retrieved May 2, 2018,

from: [http://siteresources.worldbank.org/BODINT/Resources/278027-](http://siteresources.worldbank.org/BODINT/Resources/278027-1215524804501/IBRDCountryVotingTable.pdf)

[1215524804501/IBRDCountryVotingTable.pdf](http://siteresources.worldbank.org/BODINT/Resources/278027-1215524804501/IBRDCountryVotingTable.pdf)

- World Bank Group. (2015, September 28). *2015 Shareholding Review: Report to Governors*. (DC2015-0007). Retrieved December 12, 2017, from: [http://siteresources.worldbank.org/DEVCOMMINT/Documentation/23689867/DC2015-0007\(E\)Shareholding.pdf](http://siteresources.worldbank.org/DEVCOMMINT/Documentation/23689867/DC2015-0007(E)Shareholding.pdf)
- Xu, H., Hipel, K. W., Kilgour, D. M., & Fang, L. (2018). *Conflict Resolution Using the Graph Model: Strategic Interactions in Competition and Cooperation*. Studies in Systems, Decision and Control 153. Cham, Switzerland: Springer.
- Yu, V. (2015, October 12). Communist Party powered by history? Why China's one-party rule is facing a legitimacy crisis. *South China Morning Post*. Retrieved May 1, 2018, from: <http://www.scmp.com/news/china/policies-politics/article/1865965/legitimacy-crisis-facing-chinas-communist-party>

Appendix A

Preferential Option Effectiveness

The preference ranking of states is an integral aspect of the GMCR methodology, especially for stability analysis. An extension of the Option Effectiveness approach mentioned in Section 3.2 can be considered in terms of its importance to conclude the conflict into the preferred states by the DMs. Considering the preference ranking of the states that should have been established during GMCR modeling stage, one can rank the equilibria in accordance to the state-preference rankings that they represent. The equilibria preference ranking can then be used to further strengthen an equilibrium state, meaning that not only is the stability analysis considered in the proposed approach, but also that the DM's preferences play an important role in measuring option effectiveness. Assuming that DM i 's preferences are $S_{DM_i}^{Pref} = S_1 \succeq_i S_2 \succeq_i \dots \succeq_i S_n$, where n is the total number of states and the states are ranked from most important to least important, one can map the equilibria states in the same manner such that they are ranked from most important to least important, where each E_i is mapped to its corresponding S_n in the model. For example, a GMCR model of four feasible states has the preference ranking for a DM i as $S_{DM_i}^{Pref} = S_3 \succ_i S_2 \succ_i S_4 \succ_i S_1$ and has two equilibria states such that $E_1 = S_2$ and $E_2 = S_3$ then $E_{DM_i}^{Pref} = E_2 \succ_i E_1$, since for DM i , $S_3 \succ_i S_2$. Moreover, the equilibria states are allowed to have equal preference rankings such that the DM is impartial about them. In the previous example, if $S_{DM_i}^{Pref} =$

$S_3 \sim_i S_2 \succ_i S_4 \succ_i S_1$ DM i , then accordingly $E_2 \sim_i E_1$, meaning that DM i equally prefers E_1 and E_2 .

Now that the process of ranking the equilibria in terms of DMs' preferences is clear, a weight can be assigned for each equilibrium state in terms of its preference for the DM such that the most preferred equilibria is assigned a weight $w_{DM_i} = Y$ where Y is the total number equilibria states in the model. Subsequently, the next preferred equilibrium state is assigned a weight of $w_{DM_i} = (Y - 1)$ and so on for all the remaining equilibria. Equilibria states with mutual preference rankings are assigned the same weight. Hence, the preferential strength of an equilibrium state with respect to DM i is denoted by:

$$STR_{PREF_{DM_i}}(E_y) = STR(E_y) \times w_{DM_i}(E_y) \quad (A.1)$$

Accordingly, the Preferential Option Effectiveness is computed by substituting $STR(E_y)$ in Equation 3.2 with $STR_{PREF_{DM_i}}(E_y)$:

$$EFF_{PREF_{DM_i}}(O_m) = \sum_{y=1}^Y a_{ym} STR_{PREF_{DM_i}}(E_y) \quad (A.2)$$

where

$$a_{ym} = \begin{cases} 1, & \text{if Option } m \text{ is selected} \\ 0, & \text{otherwise} \end{cases},$$

E_y is the equilibrium state, O_m is the m^{th} option, which may be selected or not under E_y , Y is the total number of equilibrium states, and M is the total number of options available.

Similar to the tabular approach for calculating the standard Option Effectiveness, one can use a tabular approach shown in Table A.1 to calculate the Preferential Option Effectiveness. Table A.1 is essentially the same as Table 3.3 with the addition of a new column at the end to represent the preferential strength of each equilibria and a new row below the option effectiveness to represent the Preferential Option Effectiveness.

Table A.1 Tabular form of Preferential Option Effectiveness approach for DM i

	O_1	O_2	...	O_M	<i>Strength of Equilibrium</i>	<i>Preference Weight</i>	<i>Preferential Strength of Equilibrium</i>
E_1	a_{11}	a_{12}	...	a_{1m}	$STR(E_1)$	$w(E_1)$	$STR_{PREF_{DM_i}}(E_1)$
E_2	a_{21}	a_{22}	...	a_{2m}	$STR(E_2)$	$w(E_2)$	$STR_{PREF_{DM_i}}(E_2)$
\vdots	\vdots	\vdots		\vdots	\vdots	\vdots	
E_Y	$a_{Y,1}$	$a_{Y,2}$	...	a_{YM}	$STR(E_Y)$	$w(E_Y)$	$STR_{PREF_{DM_i}}(E_Y)$
<i>Option Effectiveness</i>	$EFF(O_1)$	$EFF(O_2)$	...	$EFF(O_M)$			
<i>Preferential Option Effectiveness</i>	$EFF_{PREF_{DM_i}}(O_1)$	$EFF_{PREF_{DM_i}}(O_2)$	...	$EFF_{PREF_{DM_i}}(O_M)$			