Attitudes and Coalitions in Brownfield Redevelopment and Environmental Management

by

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

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Abstract

Conflict analysis tools are applied to brownfield negotiations in order to investigate the impacts of coalition formation and a decision maker's (DM's) attitudes upon the successful resolution of brownfield disputes. The concepts of attitudes within the Graph Model for Conflict Resolution (GMCR) is defined and subsequently are used, along with coalition analysis methods, to examine the redevelopment of the Kaufman Lofts property and the resolution of a post-development dispute involving Eaton's Lofts, both located in downtown Kitchener, Ontario, Canada. Within the model of the Kaufman Lofts redevelopment, the project is broken down into three connected project conflicts: property acquisition, remediation selection and redevelopment; with the graph model applied to all three conflict nodes. The application of attitudes shows the impact of cooperation between local governments and private developers in the formation of a coalition that mutually benefits all parties. Coalition analysis, applied to the redevelopment selection conflict between Heritage Kitchener and the private developer in the Kaufman Lofts project, illustrates the importance of close collaboration between the local government and the developer. Systems methodologies implemented here for the examination of brownfield redevelopments are examined and contrasted with the economic and environmental tools commonly used in the redevelopment industry. Furthermore, coalition formation within GMCR is used to examine the negotiation of the Kyoto Protocol, to demonstrate that formal conflict resolution methods can be utilized in other areas of environmental management.

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List of Acronyms and Abbreviations

$a\mathrm{AP}_{ij}b$	*a* is an aggressive preference to state *b* of DM *i* towards DM *j*
$a\mathrm{DP}_{ij}b$	*a* is an devoting preference to state *b* of DM *i* towards DM *j*
$a\mathrm{I}_{ij}b$	*a* is an indifferent preference to state *b* of DM *i* towards DM *j*
$a\mathrm{TRP}_{i}b$	*a* is a total relational preference to state b for DM *i*
$a\mathrm{RP}_{i}b$	*a* is a relational preference to state b for DM *i*
CGMR	Coalition general metarational stable state
CNash	Coalition Nash stable state
CSEQ	Coalition sequentially stable state
CSMR	Coalition symmetric metarational stable state
DM	Decision maker
EEC	Estimated environmental concentration
EU	European Union
GMCR	Graph Model for Conflict Resolution
GMR	General metarational stable state
HQ	Hazard quotient
ILCR	Incremental lifetime cancer risk
IRIS	Integrated risk information system
MCDM	Multiple Criteria Decision Making
MOE	Ontario Ministry of the Environment
Nash	Nash stable state
RfD	Reference dose
RSEQ	Relational sequentially stable state
RSMR	Relational symmetric metarational stable state
RGMR	Relational general metarational stable state
RNash	Relational Nash stable state
SEQ	Sequentially stable state
SMR	Symmetric metarational stable state
SSRA	Site specific risk assessment
$\mathrm{TRR}_i(s)$	Total relational reply list from state *s* for DM *i*
U	Unstable state

UI	Unilateral improvement
UM	Unilateral move
UNFCC	United Nations Framework for Climate Change
USEPA	United State Environmental Protection Agency
X	Non equilibrium state

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Introduction

1.1 Brownfields

Brownfield properties, defined by the United States Environmental Protection Agency (USEPA) as being abandoned, idled and potentially contaminated, are both a problem and a point of interest for urban centers around the world (USEPA, 1997). Although brownfields may be associated with reduced human health and environmental quality, higher crime rates, and carry a stigma seen by developers, citizens and local government, they also provide opportunities for reducing urban sprawl, improving human health and environmental conditions and increasing tax revenue to the local government (Greenberg, et al., 1998; DeSousa, 2003). With the opportunity to improve the social, environmental and economic conditions of an urban center, it is no wonder that municipal and city governments are clamouring to redevelop these unused properties. However, finding developers willing to undertake the considerable financial and legal risks of purchasing and developing brownfield land requires skilled negotiation. This is, of course, coupled with a need to meet the Ontario Ministry of the Environment's (MOE's) regulations for human and environmental exposure to contaminants. Satisfying the preferences of developers, local government, provincial and federal ministries and citizens requires the ability to foresee the repercussions of the actions each decision maker (DM) takes and thus benefits from the application of a conflict analysis tool.

Conflict, often arising as a result of a difference in values between multiple DMs, is a common aspect of everyone's personal and professional lives. Further, conflicts between disparate social and political groups are responsible for the vast majority of social change, be it positive or negative, in modern society. Many of these conflicts, such as labour negotiations, project management disputes and military deployment (Kilgour and Hipel, 2005), are studied in the field of conflict analysis. Regardless of the type of conflict being analyzed, the Graph Model for Conflict Resolution (GMCR) can be used to gain insights into the potential moves and resolutions available DMs in present and potential future conflicts or to provide historical analyses of past conflicts (Fang et al., 1993). Although the Elmira groundwater conflict (Hipel et al., 1993) and the Garrison Diversion Unit (Fraser and Hipel, 1984) are examples of environmental conflicts that have been analyzed previously using GMCR, brownfield conflicts represent a distinct conflict that has not been analyzed without strategic conflict tools. Brownfield conflicts are investigated herein such that the interactions that take place between developers, local government and other DMs can be better understood and paths towards better conflict resolutions can be determined.

The application of GMCR allows complicated strategic conflicts to be modelled in a straightforward, precise manner that permit DMs' interactions be examined. The goal of this is to allow for better judgement and hopefully more positive conflict outcomes that are beneficial for all of the involved DMs. In order to accomplish these tasks, the decision model requires information about each DM's options and preferences over all the feasible states in the conflict model. These preferences, as well as attitudes (Inohara, et al., 2007) can be used to define each DM's objectives in a given conflict and contributes to the final outcome.

1.2 Motivation for Brownfield and Environmental Management Research

The management of brownfield properties is a complex task involving multiple DMs each with goals that may conflict. Previous methodologies (Sounderpandian, et al., 2005; Witlox, 2005) have focused on the financial and ecological impacts on brownfield decision making whilst the strategic interactions between stakeholders in these conflicts have largely been ignored. The use of systems methodologies, such as GMCR, fits naturally to the problem of completing brownfield redevelopment projects with multiple DMs with contrasting objectives and backgrounds.

Private brownfield redevelopment projects can be analyzed as three separate conflicts; property acquisition, remediation and redevelopment. With the division of the complex problem of brownfield revitalization projects, the system is simplified into a set of manageable conflicts that are more easily understood and analyzed. GMCR, applied to these three conflicts, provides insights into how local governments can entice development and how developers can work to avoid issues with heritage committees, building inspectors and so forth.

International environmental management conflicts, such as the Garrison Diversion Unit conflict analysed by Fraser and Hipel (1984), typically contain multiple DMs acting with different goals and options towards the resolution of problems that involve environmental stewardship, politics and economics. One such problem, the Kyoto Protocol conflict between Russia, the European Union and the United States of America is analysed using new coalition analysis tools developed by Inohara and Hipel (2008a, 2008b).

The aforementioned conflicts are herein analyzed using GMCR, the systems tool which provides the theoretical basis for this thesis. The methodology relies heavily on the preference rankings assigned to each DM, with each preference ranking based on the principle that each DM prefers to improve their own lot, while holding indifference towards the improvements of all other DMs. However, if DMs hold either positive or negative attitudes towards each other, they may act against these preferences to create new conflict outcomes. Thus, the motivation behind this aspect of the research is to investigate the impacts of attitudes upon conflict outcomes. The application of attitudes to GMCR is not just of theoretical interest, as negative attitudes are common, especially in international conflicts and labour negotiations and positive attitudes are an essential part of coalition and team building, covered in Chapter 2 of this thesis.

1.2.1 Objective

The overall objective is to employ formal approaches for analysing attitudes and coalitions within the paradigm of the graph model for conflict resolution in order to investigate the strategic consequences of attitudes and cooperation in brownfield redevelopment and other areas of environmental management. To accomplish this, the redevelopment of the Kaufman Shoe Factory in downtown Kitchener, Ontario, Canada is analysed as three distinct conflicts using attitudes and coalitions within GMCR, while the post-development conflict surrounding the Eaton's Lofts project is also analyzed using attitudes. Finally, a strategic analysis of the Kyoto Protocol examines the impact of coalition movements upon the resolution of an international environmental management conflict.

1.3 Outline of the Thesis

Herein, this thesis contains four main sections. In the second section, comprising Chapters 2 and 3, the Graph Model for Conflict Analysis, Coalition Analysis and Attitudes within the graph model are defined and examples of each are shown. These two chapters comprise the theoretical portion of the thesis. In Chapters 4 and 5 which constitute the third section, Chapter 4 provides a thorough review of brownfield literature describing the various types of decision support available to DMs in the area of brownfield management and redevelopment. Within Chapter 5, GMCR is applied to two redevelopment projects, the Kaufman Lofts and Eaton's Lofts in downtown Kitchener, Ontario, Canada. In Chapters 6 is a further application of the methodologies described in Chapters 2 and 3, rounding out the third section. Additionally, the fourth section, Chapter 7 provides a summary of the findings of this research. Figure 1.1 more clearly shows this progression and relationship between the sections and chapters of this thesis.

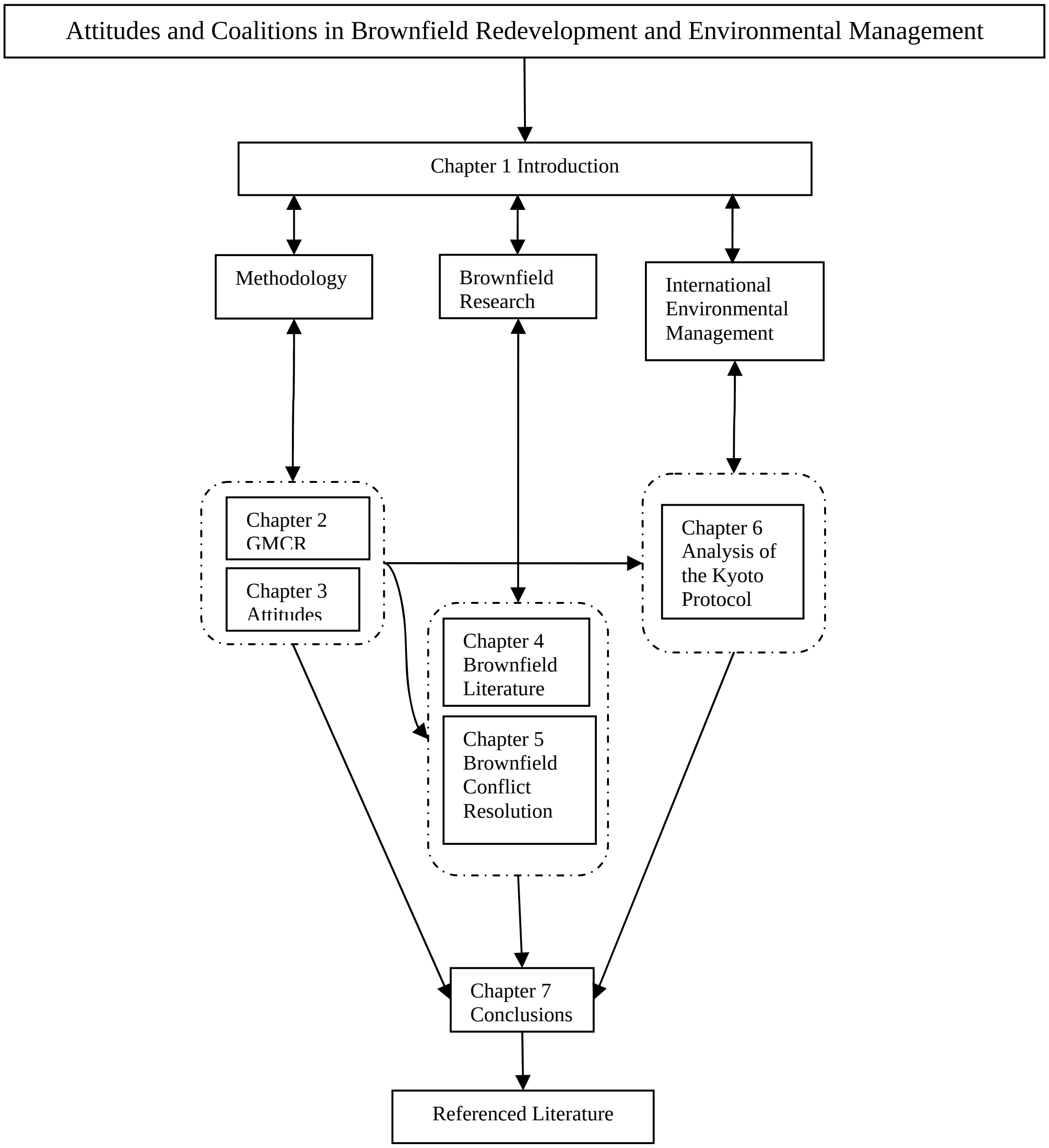

Figure 1.1. Thesis layout

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The Graph Model for Conflict Resolution

2.1 Introduction

Conflict is common to many types of human interaction and is often driven by a difference in goals or values (Fraser and Hipel, 1984; Fang, et al., 1993; Hipel and Obeidi, 2004). Thus, the study of conflict is useful for determining better courses of action when multiple stakeholders are involved. Whether it be negotiations regarding the Kyoto Protocol or the purchase of contaminated property within a city, the interactions between the various decision makers (DMs) can lead conflicts towards positive resolutions that are beneficial to all or towards negative, even catastrophic results.

A range of conflict analysis tools have been proposed to model the real life actions of DMs under conflict and the vast majority find their bases in game theory. The work of Von Neumann and Morgenstern in 1944 entitled "Theory of Games and Economics" is considered to be the founding text of this branch of conflict research. Howard (1971) furthered the concepts of Von Neumann and Morgenstern with the development of metagames and also drama theory (Howard, 1990) which breaks conflicts into three acts, similar to a drama. Fraser, Hipel and del Monte (1983) compared and contrasted four methods of conflict analysis that were available at the time and noted that metagame analysis had an advantage over previous game theoretic models due to its flexible modeling capabilities that allow it to be applied to practical conflict situations. Within the framework of metagames, Howard (1971) developed solution concepts related to whether a conflict outcome is stable for a given DM and labelled states as being rational, symmetric, general metarational or unstable. These solution concepts were developed under the assumption that a DM under conflict has knowledge only of whether a state is more preferred, equally preferred or less preferred by the DM with respect to another state (Fraser, Hipel and del Monte, 1983). This information and the concepts of reactions or movements between states allows for meaningful analyses to be carried out such that outcome stability can be determined. Howard's other major contribution to the area of conflict resolution was drama theory (Howard, 1990) in which conflicts are broken down into different acts, as in a play or drama.

In 1984, Fraser and Hipel (1979; 1984), extended metagame analysis by introducing additional solution concepts including sequential stability and simultaneous sanctioning as well as the tableau form to carry out stability calculations. Sequential sanctioning allowed for the consideration of credible solutions in which a sanction DM will not harm himself or herself in the process of levying a sanction. In 1993, Fang, Hipel and Kilgour developed the Graph Model for Conflict Resolution (GMCR) which provides a useful structure for recording the movements and countermoves of the various DMs and defining solution concepts. Within the graph model, a set of arcs represents the potential movements between vertices which stand for different conflict outcomes or states. The simple algorithm, depicted in Figure 2.1, is used to apply GMCR in the two main steps, consisting of modelling and analysis.

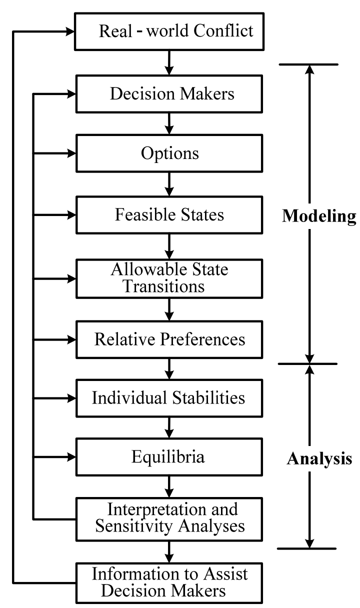


Figure 2.1. Implementation of GMCR

As can be seen in Figure 2.1, the implementation of GMCR is motivated by a real-world conflict which is then modelled. From a careful examination of the conflict, DMs who have direct impact on the conflict are determined. The options available to these DMs are ascertained and from these options a set of feasible states are created. The total set of states consists of all combinations of options as selected by all the involved DMs. Feasible states represent an important subset of the total set and include all states formed by feasible combinations of options. The allowable state transitions, determined from background research of the conflict being analyzed are used to determine how the different DMs can move between states. Finally, relative preferences are determined from historical data or information provided directly by the DMs. If the preferences are ordinal the feasible states are ranked from most to least preferred, where ties are allowed. Moreover, cardinal preferences can also be handled by the graph model, since ordinal preference information is contained within the cardinal structures. After these steps have been completed, solution concepts are applied to the model to determine individual stabilities for each DM at each state. Using these stability results, states that are stable for every DM involved in the conflict are determined and labelled as being equilibrium states (Fang, et al., 1993).

There are numerous advantages to the application of GMCR in strategic decision support. GMCR is a very flexible framework for conflict analysis which can support various kinds of information about DMs, preferences and options. The graph model can be applied using both transitive and intransitive preference information as ranking information used for determining stability is used relative to a starting state. Because all transitive preferences can be handled by the model, cardinal utility values that express a DM's preferences for different states are not necessary as in classical game theoretic methods but can still be taken care of by the model (Fang et al., 1993). Additionally, intransitivities can be modelled within GMCR. GMCR can also accommodate different types of moves including reversible, irreversible and common moves. Reversible moves refer to options that, if selected by a DM, can be unselected by that same DM while irreversible moves refer to moves that once selected, cannot be undone. A common move refers to the situation where multiple DMs can make unilateral moves from the same starting state to the same final state (Fang, et al., 1993).

2.2 Graph Model Definitions

The following definitions, developed by Kilgour, et al. (1987) and Fang, et al. (1993), are used to precisely layout the framework of the graph model including DMs' moves and countermoves, as well as the application of solution concepts within the model.

Definition 1 (The Graph Model for Conflict Resolution): A graph model for conflict resolution is a 4-tuple (N, S, $(A_i)_{i \in N}$, $(\succ_i, \sim_i)_{i \in N}$), where N: the set of all decision makers (DMs) ($|N| \geq 2$), S: the set of all states in the conflict ($|S| \geq 2$), (S, A_i): DM i's graph (S: the set of all vertices, $A_i \subset S \times S$: the set of all arcs such that $(s, s) \notin A_i$ for all $s \in S$ and all $i \in N$), and ($\succ_i$, $\sim_i$): DM i's preferences on S.

For $s, t \in S$, $s \succ_i t$ means that DM i prefers state s to t, while $s \sim_i t$ indicates that DM i is indifferent between s and t. Relative preferences are assumed to satisfy the following properties:

$\succ_i$ is asymmetric; hence, for all $s, t \in S$, $s \succ_i t$ and $t \succ_i s$ cannot hold true simultaneously.

$\sim_i$ is reflexive; therefore, for any $s \in S$, $s \sim_i s$.

$\sim_i$ is symmetric; hence, for any $s, t \in S$ if $s \sim_i t$ then $t \sim_i s$.

($\succ_i$, $\sim_i$) is complete; therefore, for all $s, t \in$ S one of $s \succ_i t$, $t \succ_i s$ or $s \sim_i t$ is true.

In Definition 1, the arcs between states represent the set of unilateral movements that a DM has between those states. Given this mathematical foundation and in order to define solution concepts for analyzing conflicts, the reachable list and unilateral improvement list are defined.

In order to adequately describe the ways that DMs move and interact under conflict it is necessary to create sets that define DM strategies and options. The symbol ϕ is used to represent three separate sets of states based on DM preferences where:

$\phi_i^+(s)$ represents the set of states preferred by DM i to state s,

$\phi_i^-(s)$ represents the set of states less preferred by DM *i* to state *s*, and

$\phi_i^=(s)$ represents the set of states that are equally preferred by DM *i* to state *s*.

An adaption of this, given in Definition 7, is used to accommodate the set of less than or equally preferred states.

Unilateral movements (UM) make up the reachable list from a given state. Let $s \in S$ and $H \subseteq N, H \neq \phi$. A UM from *s* by H, a member of $R_H(s)$, is defined inductively by:

i) if $i \in H$ and $s_1 \in R_i(s)$, then $s_1 \in R_H(s)$ and $i \in \Omega_H(s, s_1)$ ..

ii) if $s_1 \in R_H(s)$, $j \in H$ and $s_2 \in R_j(s_1)$, then

a) if $|\Omega_H(s, s_1)| = 1$ and $j \notin \Omega_H(s, s_1)$, then $s_2 \in R_H(s)$ and $j \in \Omega_H(s, s_2)$

b) if $|\Omega_H(s, s_1)| > 1$, then $s_2 \in R_H(s)$ and $j \in \Omega_H(s, s_2)$

To determine $R_H(s)$, i) adds states that are UMs from state *s* by all DMs in *H*, while ii) adds those other states that can be attained via sequences of "joint moves" by some or all DMs in *H*. In the latter case, it is necessary to screen out sequences containing consecutive moves by any DM. This is achieved by distinguishing $|\Omega_H(s, s_1)| = 1$ from $|\Omega_H(s, s_1)| > 1$: if there is only one DM in who can move to s_1, a state $s_2 \in R_j(s_1)$, $j \in H$ is a member of $R_H(s)$ if and only if $j \neq i$; if there are two or more DMs who can make a move from s_1 to a state $s_2 \in R_j(s_1)$, i.e., $|\Omega_H(s, s_1)| > 1$, then any state $s_2 \in R_j(s_1)$, $j \in H$ can be added to $R_H(s)$ because there exists a sequence from *s* to s_1 in which the last move is not made by *j*. The set $R_H(s)$ can be regarded as the reachable list of *H*, in that all states in $R_H(s)$ can be achieved by some or all DMs in *H* without participation of any DM in *N*-*H* .

When assessing the stability of a state for a given DM, it is necessary to examine possible responses by other DMs. In a two-DM model, the opponent is a single DM, while in an *n*-DM model with $n \geq 2$, the opponents are a group of two or more DMs. To extend the stability definitions in Section III-A to *n*-DM models, the definition of countermoves by a group must be introduced first. Let $H \subseteq N$ be a nonempty subset of all DMs. A UM by a group of DMs is defined by a *legal sequence* of UMs, defined below, by individual DMs in the group. In a legal sequence, a DM may move more than once, but not consecutively. Let $R_H(s)$ denote the set of all states that can be reached through any legal sequence of UMs from state *s* by some or all DMs in *H*. If $s_1 \in R_H(s)$, let $\Omega_H(s, s_1)$ be the set of all last DMs in legal sequences from *s* to s_1.

Definition 2 (Reachable list): For $i \in N$ and $s \in S$, DM *i*'s reachable list from state *s* is the set $\{t \in S \mid (s, t) \in A_i\}$, denoted by $R_i(s) \subset S$. The reachable list is a record of all the states that a given DM can reach from a specified starting state in one step. In the graph model, all states that are joined by an arc A_i beginning at state *s*, are part of the DM *i's* reachable list from *s.* A more complete, inductive definition for reachable lists follows:

Definition 3 (Unilateral Improvement (UI) list for a DM): For $i \in N$ and $s \in S$, DM *i*'s UI list from state *s* is the set $\{t \in R_i(s) \mid t \succ_i s\}$, denoted by $R_i^+(s) \subset S$. The UI list is a subset of the reachable list and includes all states which are more preferred than the starting state for DM *i*. More inductively, UI lists are defined as the intersection of a reachable list as defined in Definition 2 and the set of more preferred states. This can be expanded to include the sets $R_i^-(s)$ and $R_i^=(s)$ in a similar manner, representing the set of unilateral disimprovements and the set of equally preferred reachable states as follows: $R_i^+(s) = \phi_i^+(s) \cap R_i(s)$: all unilateral improvements for DM *i* from state *s* $R_i^-(s) = \phi_i^-(s) \cap R_i(s)$: all unilateral disimprovements for DM *i* from state *s* and $R_i^=(s) = \phi_i^=(s) \cap R_i(s)$: all equally preferred states reachable for DM *i* from state *s*

By applying Definition 1 through 3, it is possible to determine whether a state is stable using the concepts given in Definitions 4 through 10. These solution concepts are then used to determine the overall equilibrium states for the conflict.

Definition 4 (Nash stability (Nash)): For $i \in N$, state $s \in S$ is Nash stable for DM *i*, denoted by $s \in S_i^{Nash}$, if and only if $R_i^+(s) = \phi$. Thus, Nash stability occurs when a DM has no UIs from a given state and thus is better off to remain at the state.

To define the next three solution concepts, movements under the control of DMs who are members of a set or coalition of DMs, H, must be defined.

Definition 5 (Reachable list of a coalition): For $H \subset N$ and $s \in S$, the reachable list of coalition H from state s is defined inductively as the set $R_H(s)$ that satisfies the two conditions: (i) if $i \in H$ and $t \in R_i(s)$, then $t \in R_H(s)$, and (ii) if $i \in H$ and $t \in R_H(s)$ and $u \in R_i(t)$, then $u \in R_H(s)$.

Definition 6 (Unilateral improvement list of a coalition): For $H \subset N$ and $s \in S$, the strictly unilateral improvement list of coalition H from state s is defined inductively as the set $R_H^+(s)$ that satisfies the two conditions: (i) if $i \in H$ and $t \in R^+_i(s)$, then $t \in R^+_H(s)$, and (ii) if $i \in H$ and $t \in R^+_H(s)$ and $u \in R^+_i(s)$, then $u \in R^+_H(s)$.

Definition 7 (Set of less or equally preferred states): For $i \in N$ and $s, x \in S$, the set of all states that are less preferred or equally preferred to state s by DM i is $\phi_i^{\simeq}(s) = \{x \in S \mid s \succeq_i x\}$.

Definition 8 (General metarationality (GMR)): For $i \in N$, state $s \in S$ is general metarational for DM i, denoted by $s \in S_i^{GMR}$, if and only if for all $x \in R^+_i(s)$, $R_{N\backslash\{i\}} \cap \phi_i^{\simeq}(s) \neq \phi$

General Metarationality is a solution concept that can be used by a DM to determine a 'worst case' scenario for a particular state in the sense that the preferences of the sanctioning DMs are not taken into account. Hence, opponents may make moves that appear not to be credible in order to block an improvement by the particular DM.

Definition 9 (Symmetric metarationality (SMR)): For $i \in N$, state $s \in S$ is symmetric metarational for DM i, denoted by $s \in S_i^{SMR}$, if and only if for all $x \in R_i^+(s)$, there exists $y \in R_{N\backslash\{i\}}(x) \cap \phi_i^{\simeq}(s)$ such that $z \in \phi_i^{\simeq}(s)$ for all $z \in R_i(y)$.

Symmetric metarationality looks three moves ahead. First, the particular DM determines if a unilateral improvement can be sanctioned by opposing DMs, using either a credible or non-credible move. Next, the DM seeks to find out if he or she can escape from this sanction. If the opposing DMs can enforce a sanction and the DM cannot escape from it, than the state is said to be GMR stable. If all possible unilateral improvements by the DM from the new state can be blocked the state is stable according to symmetric metarationality.

Definition 10 (Sequential stability (SEQ)): For $i \in N$, state $s \in S$ is sequentially stable for *DM i*, denoted by $s \in S_i^{SEQ}$, if and only if for all $x \in R_i^+(s)$, $R_{N\setminus\{i\}}^+(x) \cap \phi_i^{\simeq}(s) \neq \phi$

Sequential sanctioning is a situation in which a DM will avoid moving unilaterally to a more improved state because an opposing DM can sanction the DM, moving the conflict to a less desired state for the particular DM. In this case, the opposing DM will only sanction the initial DM using a 'credible move'.

After performing these various analyses, the goal is to provide some form of useful information to DMs who are taking part in the conflict. The information that is provided is dependent upon the type of solution concepts used to perform the stability analyses and thus different solution concepts can be applied, dependent upon the nature of the conflict being analyzed. In Table 2.1 the amount of foresight and risk each of the solution concepts incorporates are listed.

Table 2.1. Properties of four key solution concepts within the Graph Model for Conflict Resolution

Solution Concept	Original Reference	Risk	Foresight	Disimprovements?
Nash stability	Nash (1950, 1951); van Neumann and Morgenstern (1953)	Ignores risk	low	never
Symmetric metarational	Howard (1971)	Avoids risk	medium	by opponents
General metarional	Howard (1971)	Avoids risk	medium	by opponents
Sequential stabiliity	Fraser and Hipel (1979, 1984)	Takes some risk	medium	never

Adapted from Kilgour, Fang and Hipel (1996)

Non-myopic stability (Brams and Witman, 1981) and limited move stability (Zagare, 1984; Kilgour, 1985) solution concepts round out the remaining solution concepts by allowing for high and variable foresight while taking into account strategic disimprovements. Limited move stability examines multiple moves ahead in a conflict and is often completed by examining the potential evolution of a conflict with a tree diagram. At each state, potential movements by each DM are examined and compared to the status quo state. This analysis may be extended further to create a non-myopic analysis where DMs look more than a selected number of states ahead, but infinitely ahead in search of a stable state or states.

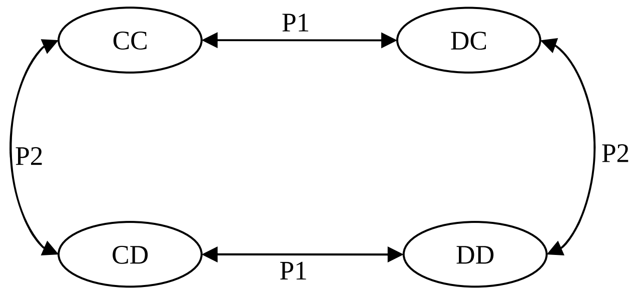
2.3 Prisoners' Dilemma

Prisoners' Dilemma, (Dresher, 1961; Flood, 1952; Rapoport and Chammah, 1965) is a simple conflict between two prisoners who worked together on some illicit activity for which both are brought into a police station and interrogated separately. Each prisoner is told that if they turn in their accomplice that they will be set free and that their accomplice will get 10 years in prison, while if their accomplice turns them in then they will go to prison for 10 years and their accomplice will go free. Both prisoners know that if they don't say anything to the police, they will receive a reduced sentence of 2 years as there is not enough evidence for the police to seek a greater charge. However, if they both confess with the expectation of being set free, they will both go to prison for 8 years. In this conflict, each of the two DMs, prisoner 1 (P1) and prisoner 2 (P2) have the option to co-operate with each other and not talk to the police (C) or defect and confess to the police (D). The combinations of these two states creates a set, *S*, of all the feasible states in the conflict. For this given conflict, all of the states are feasible and thus the set *S* = { CC, CD, DC, DD } where the first letter of the state represents the action or strategy of P1 and the second letter of the state represents the action of P2. In order to generate these states or outcomes, it is convenient to use option form. Table 2.2 below shows how the various options chosen by P1 and P2 lead to different outcomes within the conflict.

Table 2.2. Prisoner's Dilemma in option form

DM	Option				
Prisoner 1	Cooperate (C)	Y	N	Y	N
	Defect (D)	N	Y	N	Y
Prisoner 2	Cooperate (C)	Y	Y	N	N
	Defect (D)	N	N	Y	Y
State ID		CC	DC	CD	DD

In Table 2.2, a 'Y' is used to denote that 'yes', a given outcome has been selected while 'N' is used to denote that 'no', a given option has not been selected. In Figure 2.2, an integrated graph model for both P1 and P2 are shown. Included with the graph in Figure 2.2 is an ordinal ranking of states from most to least preferred.



P_{P1} = {DC, CC, DD, CD}
P_{P2} = {CD. CC. DD. DC}

Figure 2.2. Integrated model of Prisoners' Dilemma

The vertical arrows between states CC and CD and states DC and DD represent the unilateral movements that are available to P2 in the Prisoners' Dilemma. Note here that each arrow has an arrowhead at the end; this is the graphical representation of a reversible move as defined previously. The horizontal arrows represent the reversible unilateral movements of P1. Applying Definitions 1 through 10, each state of the conflict can be analyzed to determine stability and associated equilibria. The result of the stability analysis is shown below in Table 2.3, using the solution concepts listed in Table 2.1.

Table 2.3. Stability of four states in Prisoners' Dilemma

State	Solution Concepts P1	Solution Concepts P2	Equilibria
CC	SEQ, GMR	SEQ, GMR	Yes
CD	Unstable	Nash, SEQ, GMR, SMR	No
DC	Nash, SEQ, GMR, SMR	Unstable	No
DD	Nash, SEQ, GMR, SMR	Nash, SEQ, GMR, SMR	Yes

Applying the solution concepts, as shown in Table 2, it is possible to determine equilibrium states as well as analyze the impact that different solution concepts and thus different amounts of foresight and risk have on the equilibria to the conflict. Applying Nash, SEQ, SMR and GMR stabilities leads to only two unstable states and two equilibrium states. The two equilibria, CC and DD, correspond to the situations where both players Co-operate (CC) or Defect (DD). However, the solution concepts which give rise to the equilibria differ and thus the occurrences of these equilibria depend on the level of risk taken by the DMs and the knowledge that the DMs have. State CC is GMR and SEQ stable but not Nash stable for both DMs. This implies that both DMs have UIs from CC but that these UIs can be sanctioned by the opposing DM. In the case of Prisoners' Dilemma, the UI for both DMs at state CC would be to defect, in hopes of reducing their own penalty. By contrast, state DD is Nash stable for both DMs and thus there are no UIs from this state. Thus, at state DD, it is not an improvement for either prisoner to co-operate with the other. These solution concepts and the associated state stabilities in Prisoners' Dilemma exhibit the strategic foresight that can lead the conflict from negative outcomes, such as DD, to positive mutually beneficial results like CC.

It is also possible to illustrate this conflict in normal form (Luce and Raiffa, 1957) or tableau form (Fraser and Hipel, 1984). Normal form is very common in conflicts with two DMs each with two options, referred to as a two by two conflict. Table 2.4 below illustrates how Prisoners' Dilemma would be modelled in normal form.

Table 2.4. Prisoners' Dilemma in normal form

	P2	
P1	C	D
C	CC	CD
D	DC	DD

In the normal form of Prisoners' Dilemma, prisoner 1 (P1) has unilateral movements between the different rows by either cooperating (C) or defecting (D). Prisoner 2 (P2), on the other hand moves between different columns in the matrix by also cooperating or defecting. Each state in the conflict is formed by the combination of the prisoner's potential selected options with the first letter representing P1's strategy and the second letter representing P2's strategy. For example, state DC corresponds to the outcome where P1 defects and P2 cooperates.

Tableau form, developed by Fraser and Hipel (1984) to accommodate ordinal preference information in a geometric fashion gives conflict analysts a simple format which displays preferences and UIs. Often solution concepts for state stability and equilibria can be applied directly to the tableau giving a strong visual representation of the conflict and its potential outcomes.

Table 2.5. Prisoners' Dilemma in Tableau Form

Equilibrium	X	E	E	X
P1stability	Nash	SEQ	Nash	U
P1's preferences P1's UIs	DC	CC DC	DD	CD DD
P2 stability	Nash	SEQ	Nash	U
P2's preferences P2's UIs	CD	CC CD	DD	DC DD

E – Equilibrium state, X – Non-equilibrium state, Nash – Nash stable state, SEQ – Sequentially stable state, U – Unstable state

Using the tableau form in Table 2.5, it is easy to calculate the stabilities for each of the individual states, as previously defined. For example, as P1 has no UIs from states DC and DD, both states are Nash stable, by Definition 4. As there is a UI from CC to DC, P2's potential moves from this state must be analyzed in order to determine if the state satisfies any solution concepts for P1. From CC, P1 has a unilateral improvement, $R_{P1}^{+}(CC)$ = DC, from which point P2 can move to DD as $R_{P2}(DC)$=DD. As DD$<_{P1}$CC, state CC is GMR stable by Definition 8 for P1. As P2's movement from DC to DD is a UI, that is $R_{P2}^{+}(DC)$=DD, state CC is thus also SEQ stable by Definition 9. From Definition 10, CC is also SMR stable for P1 as after P2 moves from DC to DD, by the unilateral movement $R_{P2}(DC)$=DD, P1 can only move to state CD as $R_{P1}(DD)$=CD and CD$<_{P1}$CC.

2.4 Coalition Analysis

The ability to obtain accurate analyses of problems, using information about how a DM will move and interact is an essential part of the GMCR framework. An important addition to this framework is the analysis of coalitions, which examines how groups of independent DMs may act as a coalition to obtain a better conflict outcome. Coalitions have been previously studied within previous game theoretic models. Aumann (1959) developed coalition models within game theoretic models, namely cooperative games. Kuhn, Hipel and Fraser (1983) first adapted the concepts of coalition analysis to conflict analysis by developing an algorithm for determining the preferences of a coalition from the preferences of its members as well as an algorithm for ascertaining which DMs are likely to form a coalition. Kuhn, Hipel and Fraser's metric for determining who would join a coalition was based on the idea that if DMs had similar preferences, they would be likely to form a coalition throughout the duration of the conflict. Hipel and Meister (1993) developed two additional metrics for determining which DMs are likely to join together to form a coalition. Although these methodologies are useful for the analysis of permanent coalitions that form during conflict, further research was needed in the area of temporary coalition formation. Kilgour, Hipel, Fang and Peng (2001) first proposed the concepts of coalition moves and Nash coalition stability, while Inohara and Hipel (2008a), developed coalition solution concepts for sequential, general metarational and symmetric metarational stability along with implementation algorithms. Inohara and Hipel, (2008b) developed theoretical relationships among coalition solution concepts as well as between noncooperative and cooperative solution concepts. These solution concepts, which mirror those shown in Definitions 1 through 10, are as follows:

Definition 11 (Coalition improvement list): The coalition improvement list of a coalition $H \subset N$, with states s, $t \in \mathrm{S}$, $R_H^{++}(s)$ is defined as the set $\{t \in R_H(s) | \ \forall\, i \in H,\ t \succ_i s\}$. For a coalition movement to be a coalition improvement it must satisfy the following $R_H^{++}(s) = \phi_H^{+}(s) \cap R_H(s)$ meaning that any coalition improvement is both a more preferred state and reachable by the coalition, by the definitions of ϕ and reachable list given earlier.

The coalition improvement list combines the concepts of a coalition reachable list (Definition 5) and a UI list (Definition 3). This new subset of states differs from the UI list of a coalition (Definition 6) in that coalition improvement must be more preferred by all members of the coalition.

Definition 12 (Coalition less improved state): Let $\phi_H^{\simeq}(s)$ represent the set of all states that are less preferred to state s or are equally preferred with respect to state s by at least one DM in coalition H, that is, $\{x \in S \mid \exists\, i \in H, (s \succ_i x \text{ or } s \sim_i x)\}$. The set $\phi_H^{\simeq}(s)$ thus represents all the states that are not more preferred than s by every member of the coalition H.

Definition 13 (Coalition Nash stability for a coalition (CNash)): A state $s \in S$ is coalition Nash stable for coalition $H \in \mathrm{P}(N)$, denoted by $s \in S_H^{CNash}$, if and only if $R_H^{++}(s) = \phi$ (Kilgour et al., 2001; Hipel and Inohara, 2008).

Coalition Nash stability is analogous to Nash stability for a single DM (Definition 4). The difference, however, lies in the use of the coalition improvement list instead of a UI list. Thus, whenever the coalition cannot make an improvement from a state, that state is CNash for the coalition.

Definition 14 (Coalition Nash stability for a DM): For $i \in N$, state $s \in S$ is coalition Nash stable for DM *i*, if and only if $s \in S_H^{\text{CNash}}$ for all $H \in \mathbb{P}(N)$ such that $i \in H$.

If a DM belongs to multiple coalitions and each of these coalitions is CNash stable for a given state, that state is CNash for the given DM.

Definition 15 (Coalition sequentially stable for a coalition (CSEQ)): A state $s \in S$ is coalition sequentially stable for coalition $H \in \text{P}(N)$, denoted by $s \in S_H^{CSEQ}$, if and only if for all $x \in R_H^{++}(s)$, $R_{P(N \setminus H)}^{++}(x) \cap \phi_H^{\simeq}(s) \neq \phi$.

As with CNash stability, CSEQ stability is also analogous to a previously defined solution concept for unilateral movements. As in Definition 10, where SEQ stability is defined for a single DM, CSEQ stability exists such that if every coalition improvement from a state can be sanctioned by a credible move by a DM or a coalition other than the original coalition, it is stable.

In the following definitions, $\mathbb{P}(H)$ is a notation that refers to the class that a DM or coalition is in, where $\mathbb{P}(N)$ represents the class of DMs in the whole set N. Additionally, subclasses are defined such that for $H \subset N$, $\mathbb{P}(H)$ denotes the subclass $\{K \in \mathbb{P}(N) \mid K \subset H\}$ of $\mathbb{P}(N)$.

Definition 16 (Coalition sequential stability for a DM) For $i \in N$, state $s \in S$ is coalition sequentially stable for DM *i*, if and only if $s \in S_H^{\text{CSEQ}}$ for all $H \in \mathbb{P}(N)$ such that $i \in H$.

If a DM belongs to multiple coalitions and each of these coalitions is CSEQ stable for a given state, that state is CSEQ for the given DM.

Definition 17 (Coalition general metarationality for a coalition (CGMR)): For $H \in \mathbb{P}(N)$, state $s \in S$ is coalition general metarational for coalition *H*, denoted by $s \in S_H^{\text{CGMR}}$, if and only if for all $x \in R_H^{++}(s)$, $R_{\mathbb{P}(N-H)}(x) \cap \phi_H^{\simeq}(s) \neq \phi$.

While CSEQ focuses on the credible moves from opposing DMs or coalitions, CGMR stability looks at the set of all moves that can be made by opposing DMs or coalitions. In this way CSEQ is a subset of CGMR stability in the same way that SEQ is a subset of GMR stability (Definition 8).

Definition 18 (Coalition general metarationality for a DM): For $i \in N$, state $s \in S$ is coalition general metarational for DM i, if and only if $s \in S_H^{\text{CGMR}}$ for all $H \in \mathbb{P}(N)$ such that $i \in H$.

If a DM belongs to multiple coalitions and each of these coalitions is CGMR stable for a given state, that state is CGMR for the given DM.

Definition 19 (Coalition symmetric metarationality for a coalition (CSMR)) For $H \in \mathbb{P}(N)$, state $s \in S$ is coalition symmetric metarational for coalition H, denoted by $s \in S_H^{\text{CSMR}}$, if and only if for all $x \in R_H^{++}(s)$, there exists $y \in R_{\mathbb{P}(N\text{-}H)}(x) \cap \phi_H^{\simeq}(s)$ such that $z \in \phi_H^{\simeq}(s)$ for all $z \in R_H(y)$.

Where CNash stability does not take into account opposing moves and CGMR and CSMR look only potential countermoves, CSMR looks one step further to determine if there is any escape for the coalition from sanctions by their opposition. Based on the SMR solution concept provided in Definition 9, CSMR states that if a state is already CGMR stable and the coalition cannot move from the sanctioned to a state that is more preferred to the original state, it is stable.

Definition 20 (Coalition symmetric metarationality for a DM) For $i \in N$, state $s \in S$ is coalition symmetric metarational for DM i, if and only if $s \in S_H^{\text{CSMR}}$ for all $H \in \mathbb{P}(N)$ such that $i \in H$.

If a DM belongs to multiple coalitions and each of these coalitions is CSMR stable for a given state, that state is CSMR for the given DM.

The relationship between all of the various coalition solution concepts is shown in Figure 2.3. As with the noncooperative solution concepts given in Definitions 1 through 10, CGMR represents the most general solution concept encompassing all others while CNash is the most specific, a subset of all others. CSEQ is the subset of CGMR where the sanctioning coalition must use a credible move and CSMR represents the subset of

CGMR stable states where DMs cannot escape a CGMR sanction.

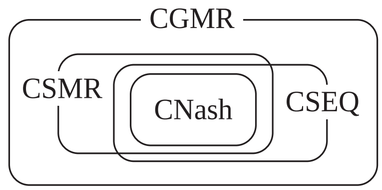
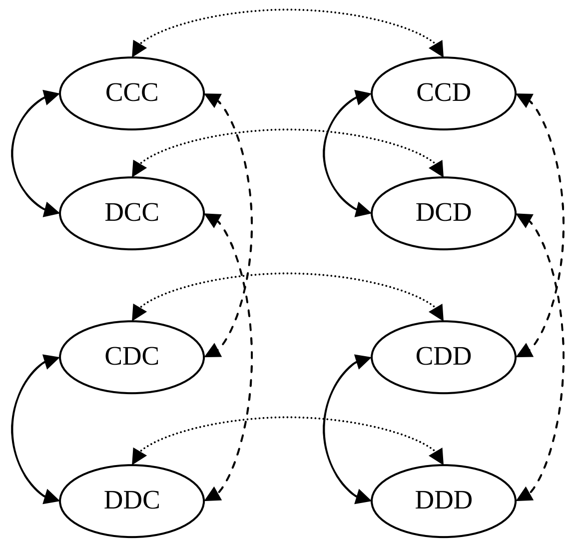


Figure 2.3. Interrelationships among Cooperative Stability Concepts

To illustrate the use of coalition analysis, a three player version of Prisoners' Dilemma is examined to illustrate the implementation of coalition analysis. In this conflict, each DM knows that if they all co-operate (C) that there will be a short sentence for all three of them. However, if they defect (D) alone, they will not be punished while if they defect with another prisoner they will have a reduced sentence. If they co-operate while one or both of the other prisoners defect, then they will have an even longer sentence. The graph model of this conflict is shown in Fig. 2.4 and is an expansion of the conflict model shown in Fig. 2.2. In Fig. 2.4, each state is represented by a three letter code made up of 'C's and 'D's where the first, second and third letters represent the first, second and third prisoners, respectively. For example, state CCD represents the state where prisoner 1 and prisoner 2 co-operate and prisoner 3 defects. Before examining the new conflict illustrated in Figure 2.4, Table 2.6 lists the algorithm used in the application of the coalition model.

Table 2.6. Coalition algorithm

Steps	**Procedures**
1	Construct the reachable lists of all possible coalitions
2	Generate the coalition improvement lists of all possible coalitions (to specify coalition Nash stability, jump to Step 6)
3	Determine the class reachable lists (needed to specify sanctions for coalition general metarationality and coalition symmetric metarationality in Step 5) and class improvement lists (required to specify sanctions for coalition sequential stability in Step 5) of subclass $\mathbb{P}(N\text{-}H)$ for each coalition $H \subset N$
4	Create the coalition improvement list table
5	Check the existence of coalition sanctions against each coalition improvement from each state (needed for determining coalition general metarationality, coalition symmetric metarationality, and coalition sequential stability)
6	Calculate the stable states for each DM
7	Determine the equilibrium states



P_{P1} = {DCC, (DDC, DCD), CCC, DDD, (CCD, CDD, CDC)}
Prisoner 1's moves are shown with a solid arrow
P_{P2} = {CDC, (DDC, CDD), CCC, DDD, (DCD, CCD, DCC)}
Prisoner 2's moves are shown with a dashed arrow
P_{P3} = {CCD, (DCD, CDD), CCC, DDD, (DDC, DCC, CDC)}
Prisoner 3's moves are shown with a dotted arrow
Note: all bracket states are equally preferred

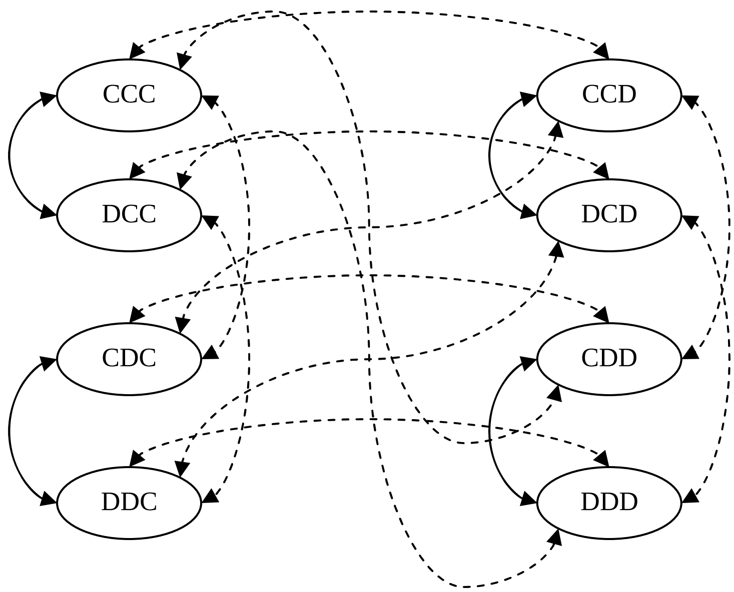
Figure 2.4. Integrated graph model of expanded Prisoners' Dilemma

Using the solution concepts covered in Definitions 1 through 10, stabilities can be determined. Table 2.3 summarizes the results of this analysis. As can be seen, in this conflict the only stable state is DDD where all three DMs defect. However, this is not one of the most preferred states for any of the DMs. Using coalition analysis, this conflict is reanalyzed to illustrate the advantage of coalitions in group decision making.

Table 2.7. Stability of eight states in expanded Prisoners' Dilemma

State	Solution Concepts P1	Solution Concepts P2	Solution Concepts P3	Eq
CCC				No
DCC	Nash, GMR, SMR, SEQ			No
CDC		Nash, GMR, SMR, SEQ		No
CCD			Nash, GMR, SMR, SEQ	No
CDD		Nash, GMR, SMR, SEQ	Nash, GMR, SMR, SEQ	No
DCD	Nash, GMR, SMR, SEQ		Nash, GMR, SMR, SEQ	No
DDC	Nash, GMR, SMR, SEQ	Nash, GMR, SMR, SEQ		No
DDD	Nash, GMR, SMR, SEQ	Nash, GMR, SMR, SEQ	Nash, GMR, SMR, SEQ	Yes

In Figure 2.5, the integrated model of the expanded Prisoners' Dilemma is shown with a coalition now formed between prisoners 2 and 3. The two prisoners maintain their preference vectors, however, they now are able to make coalition movements and improvements which are subjected to coalition solution concepts (Hipel and Inohara, 2008a).



P_{P1} = {DCC, (DDC, DCD), CCC, DDD, (CCD, CDD, CDC)}
Prisoner 1's moves are shown with a solid arrow
P_{P2} = {CDC, (DDC, CDD), CCC, DDD, (DCD, CCD, DCC)}
Coalition movements are shown with a dashed arrow
P_{P3} = {CCD, (DCD, CDD), CCC, DDD, (DDC, DCC, CDC)}
Coalition movements are shown with a dashed arrow
Note: all bracket states are equally preferred

Figure 2.5. Integrated graph model of expanded Prisoners' Dilemma with coalition

Given this new set of coalition movements a stability analysis was carried out and the solution concepts which apply to each of the states are given in Table 2.8. As can be seen a significant change has occurred due to the introduction of coalitions to the analysis. Most significantly, the state CCC, where all three prisoners co-operate is now an equilibrium state, as are states DCD and DDC where either P2 or P3 co-operate and the other two defect. DDD remains an equilibrium as it did in the previous analysis, as it is not advantageous for any of the prisoner's to co-operate if they know that the other prisoner's will defect.

Table 2.8. Stability of eight states in expanded Prisoners' Dilemma with coalition

State	Solution Concepts P1	Solution Concepts P2 and P3 coalition	Equilibrium
CCC	SEQ, SMR	CSEQ, CGMR, CSMR	Yes
DCC	Nash, GMR, SMR, SEQ	CGMR	Yes
CDC		CNash, CGMR, CSMR, CSEQ	No
CCD		CNash, CGMR, CSMR, CSEQ	No
CDD		CNash, CGMR, CSMR, CSEQ	No
DCD	Nash, GMR, SMR, SEQ	CNash, CGMR, CSMR, CSEQ	Yes
DDC	Nash, GMR, SMR, SEQ	CNash, CGMR, CSMR, CSEQ	Yes
DDD	Nash, GMR, SMR, SEQ	CNash, CGMR, CSMR, CSEQ	Yes

To illustrate how the solution concepts work for the coalition, state CCC is examined for coalition stability. At state CCC the coalition between P2 and P3, herein referred to as P23, have a set of coalition movements defined as R_{P23}(CCC) = {CDC, CCD, CDD}. The coalition improvement list, a subset of R_{P23}(CCC) where all states are more preferred for both P2 and P3 is R^{+}_{P23}(CCC) = {CDD}. When coalition P23 moves to state CDD, P1 can move to state DDD. As this move by P1 is a credible move such that R^{+}_{P1}(CDD) = {DDD} and as CCC $\succ_{P23}$ DDD, state CCC is CSEQ stable for coalition P23 by Definition 15. As R_{P1}(CDD) = {DDD} also, state CCC is also CGMR stable for coalition P23 according to Definition 17. In fact, as $R_i \subset R^{+}_{i},$ any state that is CSEQ is also CGMR.

Examining CSMR stability requires looking at the response of P1 to the sanction by P23. After P1 sanctioned P23 by moving to state DDD, P23 has the opportunity to respond. Examining the set of coalition movements available to P23 at DDD, it can be seen that R_{P23}(DDD) = {DCC, DDC, DCD}. As $\mathrm{R}_{\mathrm{P23}}(DDD) \cap \phi^{\approx}_{P23}(CCC)$ for all states in the set R_{P23}(DDD), the state is CSMR stable for coalition P23 by Definition 19.

2.5 Summary

Conflict analysis is a field of study which examines the potential actions and motivations of DMs under conflict in an effort to provide insights into the actions needed for successful win-win outcomes to occur, to determine causes of past conflict outcomes that were not mutually beneficial for all DMs and to inform policy makers. The Graph Model for Conflict Resolution is a game theoretic method which uses strategic information about a conflict including; decision makers, options, preferences and state infeasibilities. Based on the tools introduced in this chapter, attitudes will be proposed in Chapter 3 and will be applied to brownfield conflicts along with coalition analysis in Chapter 5.

3

Attitudes

3.1 Introduction

The analysis of conflict, at a strategic level, as shown through the game theoretic methodologies described in Chapter 2, attempts to take into account human behaviour under conflict (Fang, Hipel and Kilgour, 1993). An increasing amount of additions to GMCR have been proposed which allow DMs to test the sensitivity of stable states to variations in human behaviour. Li, Hipel, Kilgour and Fang, (2004) created a framework for handling uncertain preferences, while extending those solution concepts mentioned in Chapter 2 to this new structure. AL-Mutairi, Hipel, and Kamel (2008), examined the structuring of preferences using fuzzy logic (Zadeh, 1965). Obeidi, et al. (2005) examined the impact of emotions on conflict by proposing that subsets of feasible states remained hidden in conflicts due to the type of emotions DMs hold. The intent of all three of these methods is to account for variation and misunderstanding in the determination of each DM's state stabilities such that a more robust model of human behaviour can be created and applied.

Inohara, et al., (2007), developed attitudes as a method to test the robustness of conflict analysis results with the variation in how DMs perceive and act towards themselves and others. Within GMCR, preferences, UIs and coalition improvements all assume that DMs or coalitions of DMs act in a manner to improve themselves with no consideration of their moves upon others (Fraser and Hipel, 1984; Fang, et al, 1993). When applying attitudes, however, DMs may make moves and countermoves that align with their attitude towards or against the fortunes of one or more other DMs, in spite of the DM's own preferences.

An advantage of attitudes is the potential it holds for modelling co-operation within GMCR, an area that has been developed primarily through coalition analysis. As mentioned in Chapter 2, Hipel and Meister (1993), examined the formation of permanent coalitions while Kilgour, et al. (2001) and Hipel and Inohara (2008a), examined the formation of temporary coalitions and their associated solution concepts. Although GMCR is concerned with the study of non-cooperative conflicts, the application of attitudes can examine cooperative style negotiations as well as more overtly aggressive conflicts (Inohara, et al., 2007; Walker, et al., 2008).

3.2 Definitions of Attitudes

In order to utilize the concept of attitudes with the graph model, it is necessary to provide precise mathematical definitions of attitudes and the associated preference structures and movements it contains. Definitions 21 through 28 provide the structure of attitudes within the graph model while Definitions 29 through 32 provide solution concepts for calculating state stabilities under attitudes.

Definition 21 (Attitudes): For DMs $i, j \in N$, let $E_i = \{+, 0, -\}^N$ represent the set of attitudes of DM i. An element $e_i \in E_i$ is called the attitudes of DM i for which $e_i = (e_{ij})$ is the list of attitudes of DM i towards DM j for each $j \in N$ where $e_{ij} \in \{+, 0, -\}$. The e_{ij} is referred to as the attitude of DM i to DM j where the values $e_{ij} = +$, $e_{ij} = 0$ and $e_{ij} = -$ indicates that DM i has a positive, neutral and negative attitude towards DM j, respectively.

Consider a conflict, such as prisoner's dilemma analyzed in Chapter 2, which consists of two DMs called DM i and DM j. Table 3.1 displays how the attitudes within this or any other conflict can be stored in a matrix such that rows i and j contain the list of attitudes for DMs i and j, respectively, where each cell entry can take on a value of +, 0 or –. The underlying attitudes assumed in a regular analysis, where a given DM is positive towards him or herself and neutral towards his opponent are displayed in Table 3.2.

Table 3.1. Tabular Representation of Attitudes

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

Table 3.2. Attitudes in a Regular Analysis

DM	i	j
i	+	0
j	0	+

A social network, $(N, (e_i)_{i \in N})$, is the pair N, the set of DMs and $(e_i)_{i \in N}$ the set of attitudes of all DMs within the set N. Applying this pair to the framework of GMCR described in Chapter 2 entails defining a whole new set of moves and preferences. The following definitions detail these moves and preferences while providing solution concepts based upon those developed by Nash (1950, 1951), Howard (1971) and Fang, et al. (1993).

Definition 22 (Devoting preference (DP)): The devoting preference of DM $i \in N$ with respect to DM $j \in N$ is $\succeq_j$, denoted by $\mathbf{DP}_{ij}$, such that for $s, t \in S$, $s\ \mathbf{DP}_{ij}\ t$ if and only if $s \succeq_j t$.

A devoting preference is such that if DM i has a devoting preference for state s with respect to state t for DM j, then DM j must prefer state s to state t. A similar definition can be written for aggressive preference.

Definition 23 (Aggressive preference (AP)): The aggressive preference of DM $i \in N$ with respect to DM $j \in N$ is $NE(\succ_j)$, denoted by $\mathbf{AP}_{ij}$, where $NE(\succ_j)$ is defined as follows: for $s, t \in S$, $s\ NE(\succ_j)\ t$ if and only if $s \succ_j t$ is not true. That is, for $s, t \in S$, $s\ \mathbf{AP}_{ij}\ t$ if and only if $s\ NE(\succ_j)\ t$ (if and only if $t \succeq_j s$ under completeness of $\succeq_j$).

In contrast to devoting preferences, aggressive preferences are such that if DM i has an aggressive preference for state s with respect to state t for DM j, then DM j must prefer state t to state s. Using these concepts, as well as an indifference preference where the DM does not care which state is selected, represented by **I**, relational preference can be determined.

Definition 24 (Relational preference): The relational preference $\mathbf{RP}(e)_{ij}$ of DM $i \in N$ with respect to DM $j \in N$ at e is defined as follows:

$$RP(e)_{ij} = \begin{cases} DP_{ij} \text{ } if \text{ } e_{ij} = + \\ AP_{ij} \text{ } if \text{ } e_{ij} = - \\ I_{ij} \text{ } if \text{ } e_{ij} = 0 \end{cases}$$

where $\mathbf{I}_{ij}$ denotes that DM i is indifferent with respect to j's preference and, hence, $s \, \mathbf{I}_{ij} \, x$ means that DM i's preferences between state s and x is not influenced by DM j's preference.

Within the definition of relational preferences, different types of preferences are matched with their corresponding attitudes. Thus if DM i has a positive attitude about DM j, DM i will have a devoting preference with respect to DM j. If DM i has a negative attitude towards DM j, DM i will have an aggressive preference with respect to DM j. Thus, a DM behaves according to his or her attitudes and relational preferences reflect this.

Definition 25 (Total relational preference(TRP)): The total relational preference of DM $i \in N$ at e is defined as the ordering $\mathbf{TRP}(e)_i$ such that for $s, t \in S$, $s \, \mathbf{TRP}(e)_i \, t$ if and only if $s \, \mathbf{RP}(e)_{ij} \, t$ for all $j \in N$.

For a state to satisfy a total relational preference for DM i in comparison to a given state, s, the state must be relationally preferred according to the attitudes of DM i towards all of the DMs in the conflict. For example, if a state t is a total relational preference for DM i to state s with respect to himself and DM j, and there are two DMs in the conflict, then state s is a total relational preference by DM i relative to state t.

In order for a state to be a totally relational preferred state for a DM i from a state s, the state must be a relational preference at s according to the attitudes of the DM i. In Figure 3.1, DM i has relational preferences at state s according to her attitudes towards DMs j and k. However, only states t and v are totally relationally preferred as they belong to both the set $RP_{ij}(s)$ and $RP_{ik}(s)$.

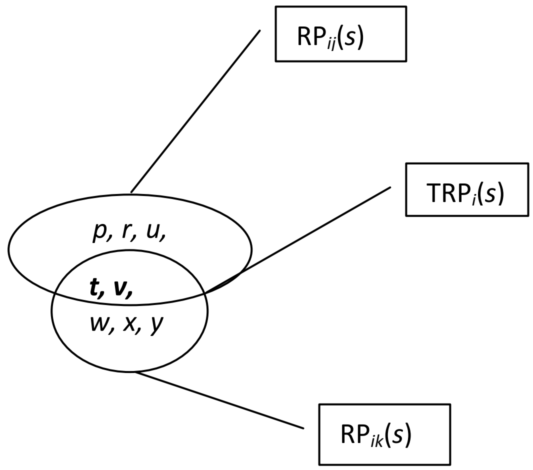


Figure 3.1. Determination of TRP$_i$(s)

Definition 26 (Total relational reply (TRR)): The total relational reply list of DM $i \in N$ at e for state $s \in S$ is defined as the set $\{t \in R_i(s) \cup \{s\} \mid t$ $\mathbf{TRP}(e)_i$ $s\} \subset R_i(s) \cup \{s\}$, denoted by $\mathbf{TRR}(e)_i(s)$.

A TRR for a given DM at some state can be seen as the relational equivalent of a UI from that same state. Continuing from Fig 3.1, total relational replies are determined from the intersection of the reachable list and total relational preferences as shown in Figure 3.2. Here, DM i has total relational preferences for states t and v and has the reachable list $R_i(s) = \{m, n, o, v\}$. Thus the total relational reply set for DM i at state s is $TRR_i(s) = \{v\}$.

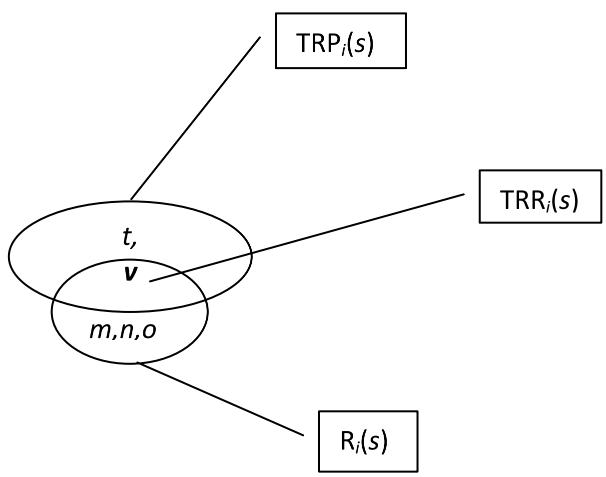


Figure 3.2. Determination of TRR$_i$(s)

Definition 27 (Total relational reply list of a coalition): The total relational reply list of coalition $H \subset N$ at e for state $s \in S$ is defined inductively as the set $\mathbf{TRR}(e)_H(s)$ that satisfies the next two conditions: (i) if $i \in H$ and $t \in \mathbf{TRR}(e)_i(s)$, then $t \in \mathbf{TRR}(e)_H(s)$, and (ii) if $i \in H$ and $t \in \mathbf{TRR}(e)_H(s)$ and $u \in \mathbf{TRR}(e)_i(t)$, then $u \in \mathbf{TRR}(e)_H(s)$.

Definition 28 (Relational less preferred or equally preferred states): The symbol $R\phi^{\simeq}(e)_i(s)$ is an analogue of $\phi_i^{\simeq}(s)$ given in Chapter 2. Hence, $R\phi^{\simeq}(e)_i(s)$ is the set of all states which are not relationally preferred to s by DM i (under attitude e). Note that NE(x $\mathbf{TRP}(e)_i$ s) means that "x $\mathbf{TRP}(e)_i$ s" is not true.

Employing the foregoing definitions, relational solution concepts can now be defined as an extension of rational solution concepts when attitudes are taken into account.

Definition 29 (Relational Nash stability (RNash)): For $i \in N$, state $s \in S$ is relational Nash stable at e for DM i, denoted by $s \in S_i^{RNash(e)}$, if and only if $\mathbf{TRR}(e)_i(s) = \{s\}$.

Definition 30 (Relational general metarationality (RGMR)): For $i \in N$, state $s \in S$ is relational general metarational at e for DM i, denoted by $s \in S_i^{RGMR(e)}$, if and only if for all $x \in \mathbf{TRR}(e)_i(s) \setminus \{s\}$, $R_{N\setminus\{i\}}(x) \cap R\phi^{\simeq}(e)_i(s) \neq \phi$.

Relational general metarationality is best described as a situation in which a DM makes a unilateral move and opposing DMs sanction that move with moves of their own. In RGMR, these sanctioning moves do not have to be total relational replies by the other DMs – they only have to be possible moves by the sanctioning DMs.

Definition 31 (Relational symmetric metarationality (RSMR)): For $i \in N$, state $s \in S$ is relational symmetric metarational at e for DM i, denoted by $s \in S_i^{RSMR(e)}$, if and only if for all $x \in \mathbf{TRR}(e)_i(s) \setminus \{s\}$, there exists $y \in R_{N\setminus\{i\}}(x) \cap R\phi^{\simeq}(e)_i(s)$ such that $z \in R\phi^{\simeq}(e)_i(s)$ for all $z \in R_i(y)$.

As in the case of RGMR, the sanctioning moves need only be possible moves by the other DMs and do not have to be either credible or relational.

Definition 32 (Relational sequential stability (RSEQ)): For $i \in N$, state $s \in S$ is relational sequential stable at e for DM i, denoted by $s \in S_i^{RSEQ(e)}$, if and only if for all $x \in \mathbf{TRR}(e)_i(s) \setminus \{s\}$, $\mathbf{TRR}(e)_{N \setminus \{i\}}(x) \cap R\phi^{\simeq}(e)_i(s) \neq \phi$.

Sequential stability occurs when one DM makes a move according to his or her total relational reply list and opposing DMs can sanction the move by moving to a state in their total relational reply lists.

One can also define what are termed "strict" versions of Definitions 22 to 32. More specifically, in Definition 22 $\succeq_i$ is replaced by $\succ_i$ to define strictly devoting preference, and in Definition 23 NE ($\succeq_i$) is replaced by NE ($\succ_i$), to define strictly aggressive preference followed by appropriate definitions and name changes made in the remaining definitions (Inohara, et al., 2007).

3.3 Attitudes and Prisoner's Dilemma

As described in Chapter 2, prisoner's dilemma is a common 2x2 conflict which examines how two prisoners who have worked together, act under conflict. In the previous analysis in Chapter 2, it was assumed that both P1 and P2 had positive attitudes towards themselves and indifferent attitudes towards each other. If different attitudes are applied to this conflict changes to state stability and equilibria results occur. In Table 3.3, two social networks are given. These social networks will be used to illustrate the impact of attitudes upon the prisoner's dilemma conflict.

Table 3.3. Social Networks for analysis of Prisoners' Dilemma

Social Network 1		
DM	P1	P2
P1	0	–
P2	–	0
Social Network 2		
DM	P1	P2
P1	+	+
P2	+	0

In Social Network 1 (SN1), it can be seen that both P1 and P2 have a negative attitude towards each other and indifferent attitudes towards themselves, thus SN1 will be used to examine prisoner's dilemma from the perspective of highly aggressive prisoners.

In Social Network 2 (SN2), it can be seen that both P1 and P2 have positive attitudes towards themselves and each other. SN2 can thus be seen as a highly devoting version of prisoner's dilemma. As both SN1 and SN2 represent situations where DMs have the same attitudes, they can be referred to as symmetric social networks. These social networks will be used to illustrate the impact of attitudes upon the prisoner's dilemma conflict.

Given the set of attitudes for SN1 and SN2, it is possible to use the concept of relational preferences to determine TRPs and TRR lists. Table 3.4 displays the type of preferences between states that are held by both P1 and P2 in SN1 and SN2. These preference types follow, of course, from the definition of total relational preferences (TRP) found in Definition 25.

Table 3.4. Applied Preferences in SN1 and SN2

Social Network 1		
DM	P1	P2
P1	$I_{P1\text{-}P1}$	$AP_{P1\text{-}P2}$
P2	$AP_{P2\text{-}P1}$	$I_{P2\text{-}P2}$
Social Network 2		
DM	P1	P2
P1	$IP_{P1\text{-}P1}$	$DP_{P1\text{-}P2}$
P2	$DP_{P2\text{-}P1}$	$I_{P2\text{-}P2}$

Using the preference information known for P1 and P2 in both SNs it is possible to determine the TRR lists for each DM at each state. In Table 3.5, each of P1's and P2's reachable lists, *R(s)*, are given from each state *s*. Using preference information, where states that are more preferred for DM *i* at some state *s* are denoted as $P_i(s)$, total relational preferences are determined for both P1 and P2 and using this information and the reachable lists already determined, total relational replies are completed.

Table 3.5. Determining TRRs in SN1 and SN2

State (s)	DC	CC	DD	CD
$P_{P1}(s)$	-	DC	DC, CC	DC, CC, DD
$R_{P1}(s)$	CC	DC	CD	DD
$P_{P2}(s)$	CD, CC, DD	CD	CD, CC	-
$R_{P2}(s)$	DD	CD	DC	CC
Social Network 1				
$RP_{P1\text{-}P1}(s)$	DC, CC, DD, CD	DC, CC, DD, CD	DC, CC, DD, CD	DC, CC, DD, CD
$RP_{P1\text{-}P2}(s)$	-	DD, DC	DC	DC, CC, DD
$TRP_{P1}(s)$	-	DD, DC	DC	DC, CC, DD
$TRR_{P1}(s)$	-	DC	-	DD
$RP_{P2\text{-}P1}(s)$	CD, CC, DD	CD, DD	CD	-
$RP_{P2\text{-}P2}(s)$	DC, CC, DD, CD	DC, CC, DD, CD	DC, CC, DD, CD	DC, CC, DD, CD
$TRP_{P2}(s)$	CD, CC, DD	CD, DD	CD	-
$TRR_{P2}(s)$	DD	CD	-	-
Social Network 2				
$RP_{P1\text{-}P1}(s)$	-	DC	CC, DC	DC, CC, DD
$RP_{P1\text{-}P2}(s)$	CD, CC, DD	CD	CD, CC	-
$TRP_{P1}(s)$	-	-	CC	-
$TRR_{P1}(s)$	-	-	-	-
$RP_{P2\text{-}P1}(s)$	-	DC	CC, DC	DC, CC, DD
$RP_{P2\text{-}P2}(s)$	CD, CC, DD	CD	CD, CC	-
$TRP_{P2}(s)$	-	-	CC	-
$TRR_{P2}(s)$	-	-	-	-

Taking the total relational replies for both social networks a simple analysis can be done in tableau form to determine the stability results. If the conflicts are written in tableau form, as previously done in the regular analysis in Table 3.5, a better vision of the new social networks and their stabilities can be seen. Table 3.6 displays the tableau form of both social networks with calculated relational stability results using only RNash and RSEQ stabilities.

Table 3.6. Prisoners' dilemma with attitudes in tableau form

Social Network 1				
Equilibrium	X	E	E	X
P1stability	RNash	RSEQ	RNash	U
P1's preferences	DC	CC	DD	CD
P1's UIs		DC		DD
P2 stability	RNash	RSEQ	RNash	U
P2's preferences	CD	CC	DD	DC
P2's UIs		CD		DD
Social Network 2				
Equilibrium	X	E	E	X
P1stability	U	RNash	RSEQ	RNash
P1's preferences	DC	CC	DD	CD
P1's TRRs	CC		CD	
P2 stability	U	RNash	RSEQ	RNash
P2's preferences	CD	CC	DD	DC
P2's TRRs	CC		DC	

E – Equilibrium state, X – Non-equilibrium state

In graph form, as shown in Figure 3.3 it is possible to see the contrast between the potential unilateral improvements available to each of the DMs under regular analysis and how these change with the application of attitudes. As can be seen in both the regular analysis and Social Network 1, P1 and P2 have the same unilateral improvements or total relational replies. This implies that when P1 and P2 hold negative attitudes towards each other it is the same as their positive attitudes towards themselves and implies that the preferences of both DMs are such that self-improvement means disimprovements for their adversary. In fact, the only situation in prisoner's dilemma where it can be observed that there are differences in the movements that the DMs will make is when they start acting with attitudes of cooperation towards each other.

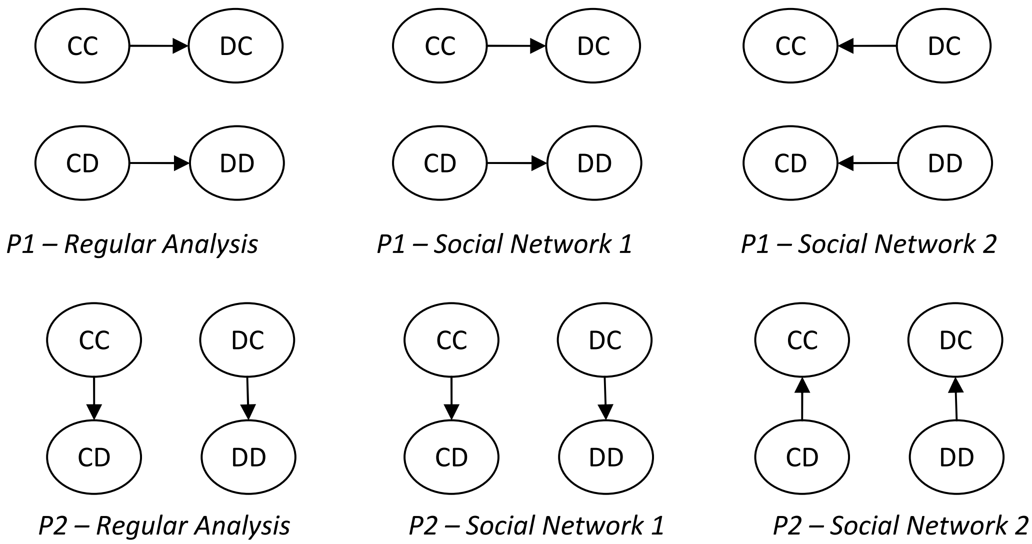


Figure 3.3. Unilateral improvements and total relational replies in Prisoners' Dilemma

Looking at the analysis of Social Network 2 more closely it is possible to explain how relational sanctioning works. In Table 3.6 both P1 and P2 have total relational replies in Social Network 2 that are the opposite of those in Social Network 1 and thus the results are significantly different. Examining P1's total relational replies it can be seen that as there exists no relationally sound movements from CC and CD, both states are RNash stable according to Definition 29. From state DC, P1 has a total relational reply to CC, according to its relational preferences as determined in Table 3.5. As P2 has no total relational replies from state CC and cannot thus respond, state DC is unstable according to Definition 29, RSEQ stability. If RGMR stability is applied, however, P2 would have a move from state CC to CD which is relationally preferred to state DC by P1 and thus state DC is not RGMR by Definition 30 for P1. At state DD, P1 has a total relational reply to state CD where P2 has a total relational reply to state CC. As CC is relationally preferred by P1 to state DD, state DD is unstable for P1. In fact, the same can be seen in an analysis of the stability of state DD with respect to P2.

3.4 Summary

By applying attitudes to the analysis of a conflict, it is possible to determine the potential impacts on conflict or negotiation resolution that arise due to DM attitudes. The application of this framework can be used to perform stability analyses and to determine new potential movements that were not credible in the regular analysis. In Chapter 5, attitudes will be applied, along with coalition analysis, to brownfield applications in order to provide further insight to this important conflict area.

4

Brownfield Literature Review

4.1 Introduction

In order to better understand the manner in which brownfield conflicts can be modelled, it was necessary to review the established literature in the area of brownfield impacts, indicators and the currently used decision support systems. Thus, this review of literature covers the area of brownfield redevelopment and examines information pertinent to the application of conflict analysis in this sector. This includes the social, economic and environmental aspects of such redevelopment as well as the attitudes, biases and preferences of decision makers in this field. Literature regarding interactions between communities and other stakeholders involved in brownfield redevelopment who may not have direct decision power is also reviewed. The main goals of this literature review are to identify what areas of research need to be strengthened to improve brownfield redevelopment and management practices, to determine the properties typical of brownfield conflicts that would aid the implementation of decision support tools and decision support systems (DSSs) and to illustrate the motivations held by decision makers (DMs) for these redevelopment projects.

The majority of literature covering brownfield redevelopment quotes the USEPA's definition of brownfields as "abandoned, idled or under-utilised industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived contamination" (USEPA, 1997). Notably, this definition is open-ended and suggests that a site need only be perceived as contaminated in order to be considered a brownfield. McCarthy notes that contamination can "…be merely suspected as well as documented" (McCarthy, 2002) in order for a property to be considered a brownfield.

4.2 Social, Economic and Ecological Impacts

Brownfield redevelopment projects impact three separate but interacting sectors: social, economic and environmental (Greenberg and Lewis, 2000; De Sousa, 2003; McCarthy, 2002). Thus, there is an interest in holistic techniques to deal with these interacting impacts.

Economic impacts are extremely important to the redevelopment of brownfields in North America. Studies have shown that the presence of brownfields within a neighbourhood can often lower property values of adjacent properties (Greenberg et al, 2000a). Also, the removal of the companies that once used the land results in a lower tax base for the whole community (Bacot and O'Dell, 2006; Knee, et al., 2001). This reduction of income for the community as a whole can often be seen in a decrease in services. This decrease in services can include reductions in police and fire support, road maintenance and garbage collection services (Greenberg and Lewis, 2000). Often this reduction in services results in further industries leaving the affected area. De Sousa (2003) and Gertler (1995) note that many of the brownfields in the City of Toronto are a result of the exodus of industry in the 1970s from the blighted downtown core.

The undertaking of the redevelopment projects themselves are often very much affected by economic factors. Financial risk due to the unknown cost of remediating a brownfield site is an important consideration for private redevelopment investors. De Sousa (2000) found that liability concerns, high remediation costs, the slow regulatory review process and complex municipal land-use policies were the most pressing obstacles to private redevelopment of brownfields. He found also that uncertainty related to the site-specific risk assessment, a lack of government incentives, obtaining financing, lack of knowledge and negative attitude on the part of the public and stakeholders were pressing financial concerns for the developers. Although there are numerous economic risks taken on by the developer, there are many economic benefits to be obtained by communities whose brownfield are redeveloped. These benefits include an increased utilization of the municipal tax base, an increase in property value and the attraction of outside investment (De Sousa, 2000; Greenberg et al, 1998; McCarthy, 2002).

In order to use this information to improve redevelopment projects, indicators have been developed. Bacot and O'Dell (2006) developed a set of indicators based on a selection of the social, economic and environmental impacts listed. The economic indicators they hypothesize for use in brownfield redevelopment are property value, parcel size, the amount of tax relief, the amount of private and public investment, market condition, end use of site, and return on investment and cleanup costs. Property value and market conditions were found by Bacot and O'Dell to be positively influenced by brownfield redevelopment. This agrees with previous research by Greenberg et al (1998, 2000), De Sousa (2000, 2003) and McCarthy (2002). Parcel size was noted as not having as significant an impact on the areas studies by Bacot and O'Dell. However, previous research by Meyer and Lyons (2000) found that larger parcels were more preferable to developers as they allow investors to "… more easily capitalize their investment" (Bacot and O'Dell, 2006).

Concerns regarding cleanup costs and investment costs were found to be unwarranted. Bacot and O'Dell determined that remediation costs averaged less than 0.5% of the total investment and as high as only 6% of the total investment. De Sousa (2000) found that remediation was approximately 1.9% of total investments for his chosen case studies although 4.3% of investors listed remediation costs as a serious economic obstacle. Tax incentives were found to be of unknown affect on the successful development of brownfields. Bacot and O'Dell suggest that although the case studies within the scope of their article are successful, a proper economic analysis needs to be done to full understand the impact of tax relief.

The environmental aspect of brownfield contamination is the most obvious and has been the root of most remediation and redevelopment work for a long time. Subsurface contamination, a common issue on most brownfield sites, can infiltrate into groundwater which in turn affects the ecology throughout the ecosystem (Murray and Rogers, 1999). The presence of these contaminants in the subsurface and groundwater is also a human health hazard. The multitude of pathways for human infection: dermal, oral and inhalation are all potentially vulnerable to carcinogens and other negative impacts from contaminants in the soil or water. Traditionally, environmental management has focused on the resolution of these issues as the keys to successful projects (Lawrence, 2000).

Environmental indicators related to impacts on ecological receptors and human health are important to the redevelopment of brownfields. Environmental risk assessors use hazard quotient calculations to determine whether wildlife is being exposed to undue harm through contamination (Rodricks, 2004; USEPA, 2006). The hazard quotient (HQ) is referred is the ratio of the dose or estimated concentration of contaminant divided by some benchmark limit for the specific contaminant. Mathematically, this is written as follows:

"(1) HQ = Dose / Screening Benchmark

(2) HQ = EEC / Screening Benchmark

Dose = an estimated amount of how much contaminant is taken in by a plant or animal, in terms of the body weight of the plant or animal (e.g., mg contaminant/kg body weight per day);

EEC = estimated (maximum) environmental contaminant concentration at the site; how much contaminant is in the soil, sediment, or water (e.g., mg contaminant/kg soil)

Screening benchmark = generally a No-Adverse Effects Level concentration; if the contamination concentration is below this level, the contaminant is not likely to cause adverse effects" (USEPA, 2006).

When the HQ is greater than 1, the contaminant is likely to cause adverse affects on the ecology. When the HQ is equal to 1 the contaminant alone is thought not to cause adverse affects and if it is less than 1 harmful effect are thought to be unlikely (USEPA, 2006). The calculation of the HQ is much more complicated than a simple division problem. Although benchmark concentrations are provided by the USEPA, it is difficult to determine a dose. From concentrations in the soil uptake factors, linear regressive equations are often used to determine a daily uptake by the animal or plant. Further information must be taken into account including the range of the animal, body weight, diet composition, % of soil in diet and exposure route. Using all of this information a dosage in the units (mg contaminant/(kg bodyweight – day)) can be calculated and compared to the no-adverse affect levels. This no-adverse affect levels is defined as "[t]he highest level of a chemical stressor in a toxicity test that did not cause harmful effect in a plant or animal" (USEPA, 2006).

Indicators of hazards to human health are broken up into two main categories: cancer and non-cancer risk (Rodricks, 2004a). Non-carcinogenic effects are measured using the hazard quotient similar to that used for wildlife while carcinogenic effects are measured using the incremental lifetime cancer risk (ILCR). The difference in the calculation of the hazard quotient for human receptors is that in the context of a site-specific risk analysis (SSRA), the exposure may be considered to be for only a few hours a day depending on the site use and the nature of the contamination. The doses for dermal, inhalation and ingestion are all calculated using different pathway dependent formulae. This dosage is then compared to a reference dose (RfD) to calculate the HQ.

(3) HQ = Dose / RfD

The HQ is interpreted in exactly the same manner as it is for ecological impacts. The RfD can be ascertained from the Integrated Risk Information System (IRIS) which is used by the large majority of risk assessors (USEPA, 2006a).

In order to determine the additional risk to humans of cancer from exposure to contamination, the Incremented Lifetime Cancer Risk (ILCR) is used. In Canada the ILCR is 1×10^{-6} which represents an increased risk of 1 in 1 million of developing cancer from exposure to a carcinogen. As with HQ calculations, a dosage is calculated for all possible pathways and combined.

(4) $$<ADD>_{life} = \frac{Conc \bullet IngR \bullet D \bullet W \bullet Y}{BW \bullet 7 \bullet 52 \bullet 70}$$

This dose calculation is referred to as the average daily dose over a lifetime $<ADD>_{life}$ which is measured in (mg contaminant/(kg body weight*day)). Specifically, the dose referred to is through ingestion of drinking water and would be used to determine uptake through drinking water. The parameters are defined as:

$<ADD>_{life}$ = average daily dose, averaged over a lifetime, mg/(kg•d)

Conc = concentration in drinking water (mg/l)

IngR = ingestion rate (l/d)

BW = body weight (kg)

D = number of days of exposure per week

W = number of weeks of exposure per year

Y = number of years of exposure in lifetime of 70 yr (Rodricks, 2004; Burmaster and Wilson, 1996)

In the case of brownfield redevelopment soil ingestion is an important potential source of exposure. Using contaminant concentrations in the soil an ingestion dosage is calculated, similar to that shown in (4) for drinking water ingestion. Uptake rates of soil for resident children, resident adults and workers are estimated to be 200, 100 and 50-480 mg/day respectively. These estimates are then used to calculate the dosage.

Dermal uptakes of contaminants in soil are estimated using an estimate of either soil-to-skin adhesion or approximate uptakes percentages. Values of adherence factors have been previously assumed to be in the range of 1.45 mg/cm^2 to 2.77 mg/cm^2 (USEPA, 2006a). However, as noted on the USEPA website "[n]ew data in this area indicates that this range should be changed to 0.2 mg/cm^2 to 1.0 mg/cm^2" (USEPA, 2006a). This change in absorption factors illustrates the uncertainty involved in determining accurate contaminant doses.

Inhalation rates for adults and children are defined in order to determine approximate inhalation exposure. For "adults [the rate] is 20 m3/day" while the rate used for "[c]hildren should be…15 m3/day" (USEPA, 2006). In order to determine the intake, however, an airborne concentration must be calculated. This is often accomplished using Henry's law as well as information regarding soil porosity and air circulation (Rodricks, 2004a).

After the dose has been calculated for ingestion, dermal and inhalation the sum of the exposure are multiplied by the cancer slope factor (CSF) to determine the ILCR. CSFs are available from the USEPA website for radionuclides and PCBs while all of the CSFs can found on the IRIS system. CSFs are often developed through bioassay on other mammal species or case studies. The combination of ILCR and HQ provide a characterization of the human health risk associated with the contamination of soil and water in brownfields.

While the ILCR and HQ require some complex calculations, they are not exact representations of the contamination of the system. Risk assessors must make assumptions with varying amounts of uncertainty in order to characterize the risk to the system. Sources of uncertainty include natural variability in ecological characteristics and responses and uncertainties in the test system and extrapolations (USEPA, 1992). Thus, an uncertainty analysis is an important element of environmental risk assessments.

The environmental and economic impacts have a significant affect on the social situation within the community affected by the brownfield. Often these sites are in neighbourhoods with higher crime while vacated sites become a haven for drug sales and other illicit activities (Greenberg et al, 1998; De Sousa, 2000). As there is a decrease in the amount of police and fire service in these areas, it becomes easier for crime to prosper. The blight itself and the contamination or perceived contamination keeps others from moving to the community and thus further impacts the social structure of the community. The positive social impacts include an increase in community services, increased quality of life, increased community health and urban renewal (De Sousa, 2000; Greenberg et al, 1998; McCarthy, 2002; Bacot and O'Dell, 2006).

Greenberg and Lewis (2000) studied brownfield redevelopment in an ethnically diverse urban setting. They found that community participation rates in brownfield redevelopment were related to participation in previous community projects. This relationship corresponds to McCarthy's 2002 findings that community goals are an indicator of the responses communities will have been to brownfield redevelopment projects. Greenberg and Lewis also found that ethnicity and the amount of time a person had been a resident did not have an impact on their interest on brownfield redevelopment.

One movement that is finding greater prominence in brownfields literature is the redevelopment of brownfields as green space. De Sousa (2003) and Grimski and Ferber (2001), note that the focus of European brownfield redevelopment activities has been on the transformation of blighted lands into park lands. This, De Sousa notes, is in stark contrast to North American brownfield projects which have focused primarily on commercial and industrial developments. De Souse notes that there are four separate types of parks that all play an important part in the urban landscape as defined by the City of Toronto. These types of parks are: parkettes, local park, district/city parks and natural heritage areas. Each of these parks plays an important role in the social and environmental structure of the city. Parkettes, local parks and city parks offer recreational facilities to neighbourhoods, communities and the city, respectively. Natural heritage parks offer environmental refuge within the city that is both aesthetically and ecologically important.

Lerner and Poole (1999) explain that there are many economic benefits to be taken from the creation of open space within cities. They cite many case studies of formerly industrialized American cities that, by utilizing their vacant land for parks were able to promote significant economic gains for the community. Chattanooga, Tennessee is examined for its implementation of a 75-mile wide green space between 1988 and 1996. Over this period, Lerner and Poole tell us, total assessed property value increased by an estimated 127.5%. The city tax revenue also expanded, increasing by 99% over the 8 year period. An interview by the researchers with city chairman David Crockett reveals the misperceptions that can interfere with the development of parks. Crockett notes that while he was first working to implement park systems in Chattanooga, “People asked why we should spend money on walking paths and parks when we have schools that need money and roads to fix and we need to create more jobs. But now we have moved beyond thinking of those as tradeoffs. It is understood that we invest in all of those things. There is consensus that we will continue to add more parks, open space, and walking areas to the city" (Lerner and Poole, 1999). The National Parks Service (NPS) noted in 1983 that the creation of park land results in a myriad improvements including: “job creation, business stimulation, increased consumer spending, property value increases, attraction of relocating/new firms, reduced impact of natural disasters, health care savings, infrastructure savings, public service savings” (Greenberg and Lewis, 2000).

Among the many benefits of park land development are environmental and social improvements. Environmentally, the development of parklands in ecologically significant areas can decrease the need for water filtration processes. Improvements to pollution control and noise abatement as well as improved air quality are related to the introduction of open space into the urban setting (NPS, 1983). The creation of parkland gives planners and engineers a way to fight urban sprawl, flooding and erosion while preserving the natural ecology (Greenberg et al, 2000). New York City, for example, has developed parks on some of its upstate watershed land in order to reduce the need for water filtration further down stream. This development, Lerner and Poole explain, is in response to the deleterious impacts of the development of watershed land. The high cost of maintaining drinkable water; as well as the serious affects on the ecology is important reasons for protecting these areas and developing open space or park land on these sensitive sites. Similarly, the Trust for Public Land and the Open Space Institute created natural heritage parkland in the state of New Jersey which helped preserve habitats for a number of animals and preserve 150,000 acres of valuable forests. This project additionally protected seven miles of the Appalachian Trail, an important recreational area (Lerner and Poole, 1999).

In Greenberg and Lewis' study of brownfield redevelopment in an urban setting of mixed ethnicity (2000), he found that the majority of residents preferred the development of a park over all other potential development options. In, fact the researchers found that 90% of respondents to their survey preferred that brownfield land be redeveloped to hold a park. Lafortezza, et. al (2004) explain that when a Brownfield to parkland transition is done properly the reclaimed land can "…increase the survival of wildlife population and the establishment of recreational activities" (Lafortezza, et. al, 2004). De Sousa (2000) also explains that the redevelopment of brownfields into parklands can help destigmatise neighborhoods that have long been blighted. These benefits can lead to improved quality of life for the inhabitants of the community through recreational activities, increased interaction and increased social and cultural activities (Gold, 1973). This in turn leads to "increased exercise and recreation, delayed aging process, mental health improvement, reduction of stress, improved sleep, aggression control, increased opportunity for motor skill development in children [and opportunity for] weight control" (Greenberg et al, 2000). Additional social benefits come through the improvement of the community. Parks notably reduce crime, increase community pride and stabilize neighborhoods.

The indicators of brownfield redevelopment cover the spectrum of environmental, social and economic areas. Social indicators are often qualitative and thus difficult to measure. Greenberg et al (1998, 2000), De Sousa (2003) and Bacot and O'Dell (2006) all utilize case studies to gather an understanding of the impact of social indicators on the success of brownfield redevelopment. Unless a large number of case studies are carried out the results may be enough to "make an important contribution to the knowledge" but not to generalize the demographics and their impacts upon brownfield redevelopment (Dair and Williams, 2005, 1347). Thomas (2003) acknowledges that the wide array of stakeholders with varying views have a significant impact on the implementation of brownfield projects. Thus accurate social information transferred to the appropriate decision makers is necessary so as to ensure that projects have positive social outcomes (Thomas, 2003).

Economic indicators are often taken from a wide range of sources including federal and local government offices as well as individual investors (Bacot and O'Dell, 2006). They also note that because the data comes from such a wide array of sources it is difficult to create useful performance vectors that are practical and relevant. Bacot and O'Dell also point out that experience on the part of investors and local government, though perhaps difficult to measure, is a key impact upon the economic success of a brownfield redevelopment project. Additional to experience, risk and uncertainty are extremely important aspects of the projects that affect the economic success of brownfields projects. Meyer and Lyons (2000) note that the strict liability put upon land owners from the 1980 Superfund act in the United States has increased the importance of economic uncertainty and risk in redevelopment projects. Here in Canada, Site Specific Risk Assessments are carried out on behalf of land owners to reduce the amount of risk and liability to the landowner (MOE). However, the uncertainty when acquiring the land as to the extent of remediation and the high cost of insurance remain important barriers to brownfield redevelopment here in Canada (De Sousa, 2000).

The environmental indicators affecting both the human health and wildlife receptors are based upon uncertainty and risk. Although risk can be quantified, as shown in the calculation of Incremental Lifetime Cancer Risk (ILCR) or through the use of Hazard Quotients (HQ) or Hazard Indices (HI), there still remains uncertainty as to the affect of brownfields on the ecology and public health. Greenberg and Hollander (2006) worry that public health benefits are being "inferred rather than being estimated" (Greenberg and Hollander, 2006) in some cases. Their concern is not that appropriate indicators don't exist in the United States to tackle environmental brownfield concerns, but rather they are concerned as to whether analysts will apply this data.

Health Canada notes that "any level of exposure (other than zero) is associated with some hypothetical cancer risk" (Health Canada, 2005). The development of the 1-in-10^6 risk of cancer due to some contamination was "purely arbitrary" but has come to represent what Health Canada and the Ministry of the Environment see is an essentially negligible amount of carcinogen. The EPA notes that although threshold indicators are the most important in the environmental remediation of a Brownfield. However, they note that cost-effectiveness, long and short-term effectiveness and the reduction in volume and toxicity are also important factors (USEPA, 2006b). Burmaster and Wilson (1996), argue that the use of point values instead of probabilistic ranges to describe the potential environmental risk is short cited. Thus, although there are definite methods that are currently in place to measure the environmental impacts of redevelopment, there is some question as to their enforcement and their usefulness.

In summary, Table 4.1 lays out the various indicators used in assessment of brownfields and renovated brownfield projects mentioned previously. While not a comprehensive list of indicators they provide a wealth of information regarding the success of a brownfield project or the impact of an undeveloped brownfield.

Table 4.1. Examples of indicators of brownfield presence and redevelopment

Type of Indicator	Examples
Social	• Crime rates • Community pride • Availability of municipal services • Community migration rates
Economic	• Municipal tax income • Reduction in municipal expenditures • Real estate prices • Availability of housing
Environmental/Health	• Wildlife Exposure Levels • Hazard Quotient • Incremental Lifetime Cancer Risk • Presence of greenfields • Biodiversity • Pollution levels • Noise levels

The large number of social, economic and environmental indicators that have been developed figure into all brownfield redevelopment projects. However, the uncertainty of the data and the breadth of sources and methods needed to obtain said data remain as obstacles to Brownfield redevelopment.

Dair and Williams (2006), De Sousa (2003; 2000) and Greenberg et al (1998; 2000) all conclude that the key decision makers are private and public developers, federal or provincial government agencies and community groups. All of these decision makers have interest in the environmental, social and economic impacts of Brownfield redevelopment. Including this wide range of decision makers in a holistic approach is important to the success of Brownfield redevelopment (Lawrence, 2000; McCarthy, 2002). The conflict, uncertainty and risk in all three important sectors affect all of these decision makers.

4.2.1 Global Trends in Brownfield

While brownfields are a phenomenon that is global, the vast majority of literature available deals with the redevelopment of such properties within Canada and the United States of America (USA). However, due to the movement of industry from developed nations to developing nations, all of Europe as well as North and South America are faced with an increasing number of brownfields.

The USEPA's information about tolerable concentrations of contaminants as well as the integrated risk information system (IRIS) is not just used in the USA but in Canada and abroad as the USEPA has set the standard in brownfield information systems (USEPA, 2006; Rodricks, 2004).

4.3 Decision Support Tools for Brownfield Applications

Conflict models and decision support systems are an increasingly important aspect of environmental management (Hipel, et al, 1993; Thomas, 2003). The key element which makes DSSs necessary in brownfield redevelopment is the high amount of uncertainty. From the very definition of brownfields proscribed by the USEPA there is uncertainty in the extent and existence of contamination at most brownfield sites (Greenberg et al, 1998; McCarthy, 2002). Additionally, there is uncertainty to remediation and legal costs, future liability and legal risk as well as the amount of time necessary to undertake the projects. Coffin (2003) notes that there is an uncertainty as to even how many brownfields are present in many communities. Thus, the implementation of an appropriate decision support tool must be done with a high amount of research. This research refers not only to case studies of similar developments but to an inventory of the brownfields and contamination in a given region. Such research or the adoption of a brownfield information system is needed for the affective use of a decision support tool. To attempt to deal with uncertainty there are many different types of decision support tools, some of which have been applied to the field of brownfield redevelopment. Within the area of brownfield redevelopment there are two distinct types of decision support tools that can be found in literature and in practice. The first type is simply an accessible information system which is used by the decision maker to fully comprehend the problem. The second type of decision support tool is a system that attempts to synthesize a set of information be it social, economic or ecological to give strategic and tactical information. This second type of decision support tool is referred to as a decision support system (DSS) and often involves the use of an analytical model. Both types of decision support tools have their place within brownfield redevelopment and will be examined in this review.

A number of information resources are operated to aid brownfield decision makers in dealing with the risk and uncertainty involved in the redevelopment process. The USEPA maintains a website outlining human health risks, preliminary remediation goals (PRGs) and risk assessments for brownfield sites. The human health website outlines the calculation of exposure ratios and hazard quotients (USEPA, 2006a) This information is pertinent to all risk assessors and is valid not only in the United States but is referred to by the Health Canada Brownfields technical appendix as a valuable technical resource (Health Canada, 2005). The USEPA's PRG website gives information about soil calculations and physical chemical data and is intended to aid in the development of PRG "...tools for evaluating and cleaning up contaminated sites" (USEPA, 2006b). The final link noted here is that dealing with the 8-step layout of the risk assessment and management procedure. This resource allows assessors and other stakeholders to view the process that is undertaken in a brownfield management project. The 8 steps outlined by the EPA are screening evaluation, exposure and risk calculation, problem formulation, study design, field sampling plan, site investigation and data analysis, risk characterization and risk management (USEPA, 2006). In order to follow through and properly remediate, the indicators examined in the first section of this review are applied, through information on these websites to determine the appropriate actions.

In the UK, the Environmental Information System for Planners (EISP) is a useful online resource for planners. The EISP is set up to assist decisions in strategic planning, pre-planning enquiries and development control decisions. Specifically, this DSS looks at: "…air quality, shallow undermining, landslide susceptibility, groundwater protection, flood risk, drainage, land contamination, proximity to landfill, biodiversity, natural and man-made heritage" (Culshaw, et al., 2006), all of which are essential environmental components to brownfield redevelopment.

The goal of the EISP resources, similar to those of the USEPA risk management website is to "…make available to non-specialists, models, information and understanding covering a wide range of relevant scientific disciplines" (Culshaw, et. al, 2006, 236). The system is complex, using GIS to determine important information during the pre-planning stage. The development control function of EISP is set up to "identify any primary constraint that has been triggered, and lead the user into the relevant decision flow diagram, providing more detailed advice on, and analysis of, the environmental concerns" (Culshaw, et. al, 2006). This system, much more detailed than the framework offered by the USEPA website, allows the planner access to a myriad of planning data, modeling information and scientific knowledge. The strategic planning module is an extension of development control function module and gives the user access to information at a local level. The system also includes flowcharts outlining the decision process for the use within the UK planning framework (Culshaw, et. al, 2006).

The EISP is a highly powerful system that provides planners and non-technical users with the information needed to implement a planning development. As the environmental issues addressed by the system are similar to those found in brownfield redevelopment projects, EISP seems to be an ideal system for addressing brownfield problems. The system although extremely successful is limited unfortunately to only environmental issues, as is the USEPA website, and thus can only aid in the minimization of environmental impacts.

In Thomas' 2003 paper, a GIS-based decision support tool is suggested for the brownfield development process. This decision support tool was intended to "(1) determine multi-stakeholder goals for site development, (2) identify and locate databases held by existing subcontractors; (3) determine a set of environmental indicators to quantify relevant factors and measure project success; and (4) identify specific brownfields sites to demonstrate the decision support application" (Thomas, 2003). This system used site-specific data including geophysical data, socioeconomic factors, contaminant location and extents as well as the previous and future land use of the land to organize the sites and to establish trends.

In order to implement the decision support tool, a number of previous developed systems were drawn upon. The Regional Online Brownfields Inventory Network (ROBIN) was one such inventory website. Here, Thompson found information about the sites available in Michigan including the size, level of contamination and the available infrastructure. Unfortunately, as of the writing of this literature review, the ROBIN network was no longer online and thus the information is unavailable to decision makers.

Thompson notes that information for the selection of a redevelopment site has already been established by Devine (1996) and lists them as "… (a) an accurate inventory of available sites; (b) environmental compliance status, history of incidents, and any enforcement actions; (c) transportation access; (d) presence of linked industries; (e) availability of development incentives; and (f) labor pool characteristics" (Thompson, 2003). To define what land uses are preferable on a brownfield the researcher lists some criteria which may affect the final use. The criteria include legal restrictions, physical restrictions, and types of contamination, community desires, site selection and professional judgment. All of these criteria represent important inputs into the decision support tool being developed. Further rankings were used to assign a quantitative value to the somewhat qualitative characteristics of the brownfields. Using the outcome from these rankings, as well as inventory information a visual aid could be created in GIS to display the inventory of brownfields in the region along with how these brownfields fit into the criteria for site selection noted above. Thompson found that a number of things needed to be improved in order to better improve the application of the decision support tool including a better analysis of user needs, more detailed and accurate information and the development and use of indicators to explain the state of a brownfield redevelopment project.

Sounderpandanian, et al. (2005), investigated the use of DSS to aid economic brownfield negotiations and proposed a system, which uses utility values and formulates the funding problems as an optimization problem solved using Solver in Microsoft Excel. As often there is limited information on whether there actually is contamination at the site, such information is often only found when the property changes hand and the contamination must be disclosed. Thus, the researchers propose that there are three main decision makers involved in the process of brownfield remediation: the owner, purchaser and the government. Using a willing to pay (WTP) factor, the DSS maximizes each DMs utility value to find an optimal solution that meets the restraints of the funding each DM has available. For each scenario, all three decision makers' WTP, subjective probability (SP), estimated income (EI), utility function, total cleanup cost (X) and optimal payment (OP) are determined. If the sum of the WTPs is greater than or equal to the cost of the project, then the algorithm does not need to be run. However, as it often is not, a solution must be found to maximize each decision maker's utility. As they note, costs are continuously distributed but are estimated in discrete amounts. Thus, the cost distribution is analyzed using an approximation developed by Clemen and Reilly (2001). Solving the associated utility functions, based on an estimated risk an optimal outcome is determined.

Looking into the repercussions of the various environmental and management affects that can be observed in environmental management conflicts, Sounderpandanian et al., 2005 express these in terms of costs. The ramifications are that although the analysis is a useful means of expressing the economic difficulties encountered by a number of decision makers negotiating how much to contribute to a brownfield redevelopment project, applying cost values to socioeconomic and ecological goals is incredibly difficult. Thus, although the DSS is a useful tool for economic negotiators, it does not take into account the full picture of why decision makers invest the amount of money and effort that they do towards specific goals.

Multiple Criteria Decision Making (MCDM) is a method of "assessing and comparing alternative solutions according to conflicting criteria" (Fraser and Hipel, 1984). Regan et. al (2005) uses MCDM to justify the need for formal decision making models in the field of environmental management, generally. Justifying the need for structured decision making they point out that "[g]roup decision making is often the result of a laborious course of unstructured negotiation that rarely yields repeatable results or outcomes acceptable to the entire group" (Regan et. al, 2005).

To implement MCDM, the researchers first set up a decision tree containing the main points of criteria. In the case of the research proposed here, the branches of the tree were "(i) Improves quality of urban system; (ii) Provides for multiple park and recreational opportunities; (iii) Physical and visual accessibility; (iv) Regional strategic significance; (v) Threats; and (vi) Restores and maintains natural resource and/or working landscape values" (Regan et. al, 2005). The criteria noted here was further broken down into sub-criteria that explained in a more detailed fashion, the criteria being examined. The analytical hierarchy process (AHP) developed by Saaty (1980) is used to weight the various parts of the decision tree. Using this weighting system, the researchers give weight to the various criteria proposed according to a rank given by the stakeholder or DM themselves. Under the AHP weighting was developed to fit the framework established by the California Legacy Project (CLP).

In the convergence model used to solve the system, "n agents with initial criterion weighting assignments $p_1^0, p_2^0, \ldots p_n^0$ for a particular hypothesis" are "assign[ed] a weighting of respect, w_{ij}, for herself and the other agents', j, positions, where $\sum w_{ij} = 1$" (Regan et al., 2005). The greater the value of wij the greater the weight that i places upon j and so forth. Upon, the first iteration, player i's criterion weight will change and thus will be the weighted sum of the other criterion weights, as shown.

$$p_i^1 = w_{i1}p_1^0 + w_{i2}p_2^0 + \ldots + w_{in}p_n^0, \quad i = 1, \ldots, n.$$

This iteration continues until a consensus is achieved and all the criterion weights are equal. Using this tool, a group consensus can be reached on how to weight different criteria that is important to brownfield redevelopment.

Regan, et al. claim that the most important intuition taken from this model is that consensus in a group setting can be achieved in time if each player or group member gives some weight to others opinions. It is suggested by the researchers that as the formal model can show convergence and thus consensus, the burden of proof is on informal models to show their usefulness in urban planning.

The development of technological DSSs and formal models in land-use planning has led to not only the use of GIS systems (Thomas, 2003) and MCDA (Regan et al., 2005) but also to the use of expert systems (ES) or knowledge-based systems (KBS) (Witlox, 2005). KBSs are seen as a refinement of artificial intelligence, where computer programs are developed to emulate human decision-making. In order to create the KBS, information is transferred from literature or human experience to a computer system or program. Citing Ortolano and Perman (1987), Witlox (2005) notes that there are 6 key criteria to be considered when implementing a KBS. "These conditions stipulate that: (i) the knowledge is specialized and narrowly focused (precisely stated or well defined), (ii) true experts in the problem field exist, (iii) the task to be performed by the system is neither trivial nor exceedingly difficult, (iv) the conventional techniques (i.e. other computer programmes, spreadsheets) are inadequate to perform the task, (v) the payoff from the KBS is significant, and (vi) the expert(s) is (are) willing to cooperate" (Witlox, 2005, 438).

Witlox notes that although the "state of knowledge in the field of … locational planning is insufficiently good to permit its representation and integration in an intelligent automated planning (expert) system…this does not mean that KBS will have no role to play in locational planning" (Witlox, 2005, 439). Further he argues that the use of KBS as a DSS is justified as DSSs often deal with unstructured or semi-structured problems.

The Matisse-Knowledge Based Decision Support System (Matisse-KBDSS) was developed by Witlox in his 2000 paper. The system uses three criteria to aid in the determination of a site location; site conditions, investment considerations and operating considerations. Using this criteria, Matisse-KBDSS matches "…the spatial production requirements of an economic activity (i.e. the actor) with the attributes characterizing the location alternatives (i.e. the object)" (Witlox, 2005). In many ways the Matisse-KBDSS acts like a multiple-criteria-decision-maker (MCDM) tool where a decision maker must choose between a group of possible options by using weighted selection criteria.

The implementation of Matisse-KBDSS as well as MCDMs are important tools for making complex decisions. However, the key pitfall of both of these systems is that they take into account only one decision maker. Studies by Greenberg (1998), McCarthy (2002), De Sousa (2003, 2002) and Dair and Williams (2006) amongst others note that the implementation of brownfield redevelopment projects is a process that involves many interest parties.

To summarize the use of decision support systems in brownfield redevelopment, Table 4.2 lists the advantages, disadvantages and areas of application of those reviewed in the proceeding section.

Table 4.2. Decision support systems and decision tools in brownfield redevelopment

Decision Tool (Reference)	Advantages/Disadvantages/Application
USEPA Brownfield Risk Management Websites (USA), Environmental Information System for Planners (UK)	• Sets out stringent remediation guidelines • Outlines goals of remediation • Tactical information • Does not provide specific case based information but general information • Applied to risk assessment calculations
GIS (Thomas, 2003)	• Determine multi-stakeholder goals for site development • Identify and locate databases held by existing subcontractors • Determine a set of environmental indicators to quantify relevant factors and measure project success • Difficult to determine the state of projects • Applied to determination of availability of brownfield lands and the success of previously redeveloped properties
Willingness to Pay /Cost Distribution (Sounderpandian, et al., 2005)	• Tactical support tool used to determine cost-sharing between seller, buyer and local government • Used to determine multi-stakeholder goals for site development
Multiple Critera Decision Making (Regan, et al., 2005)	• Multiple criteria ranked using analytical hierarchal process to determine viability of a brownfield project: Improves quality of urban system; (ii) Provides for multiple park and recreational opportunities; (iii) Physical and visual accessibility; (iv) Regional strategic significance; (v) Threats; and (vi) Restores and maintains natural resource and/or working landscape values • Allows decision makers to rank developments based on pre-defined criteria to determine an acceptable group outcome • Relies on numerical scores to determine weights that may be qualitative in nature • Based on decisions of one DM or group of DMs • Applied to redevelopment plan selection; group consensus
The Matisse-Knowledge Based Decision Support System (Wiltox, 2005)	• Aid in the determination of a site location • Uses three criteria: site conditions, investment considerations and operating considerations • Based on decisions of one DM or group of DMs

The application of GMCR, as described in Section 4.4, represents a potential exploration of strategic decision support, an area that has been until recently,

4.4 Strategic Brownfield Decision Tools

The majority of brownfield DSSs developed so far have focused on the economic and environmental issues at play. Web resources such as the USEPA and Health Canada give important technical data while the EISP system uses the power of multiple servers and GIS to allow planners access to important technical and demographic information. Other systems such as the EISP system developed by Thomas (2003, 2006) and the

ROBIN system attempt to provide accurate inventories of land for urban planners and city consultants.

There has also been a large development of more complex, mathematical systems in the area of brownfield redevelopment as well. The MCDA method developed by Regan et al. (2005) allows for the analysis of land use decisions using weighted criteria chosen by the involved decision makers while Sounderpandanian et al. (2005) use a convergence method to negotiate financial disputes between the buyer, seller and local government in brownfield sale conflicts. However, there is a gap in the development of methods to analyse and resolve the strategic-level conflicts that are involved in the brownfield redevelopment process. Applications of the Graph Model for Conflict Resolution to strategic analyses of environmental conflicts are well-documented, as noted in Chapter 1. The use of the GMCR models explained in this review is a logical next step in the analysis of brownfield conflicts. Walker et, al. (2008), broke down brownfield conflicts into three sections as shown in Figure 4.1 for the application of GMCR to brownfield redevelopment projects. A more specific model is shown in Chapter 5 in the analysis of the Kaufman Lofts renovation.

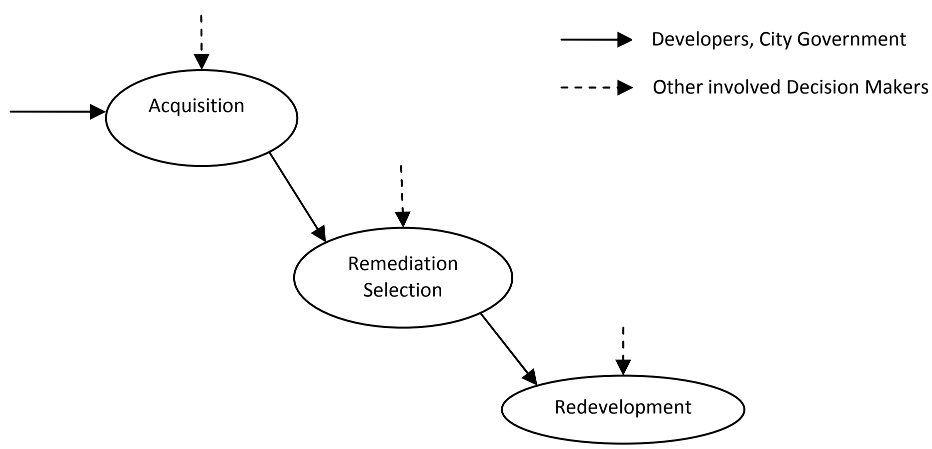


Figure 4.1. Series of conflicts in brownfield projects

An important reason for developing methods to apply GMCR to brownfield redevelopment is its relative simplicity. Slee (2006) notes that although the framework may seem mathematical to some it can be used to quite clearly show how individual decisions can interact to create an undesired or unexpected outcome. Simple games such as chicken, important philosophical concepts such as the ‘tragedy of the commons’ (Hardin, 1968) and environmental resource allocation and restoration conflicts (Fraser and Hipel, 1984; Hipel, et al., 1993) have all been shown to fit within this framework. The models developed by Fang, et al. (1993), Fraser and Hipel (1984) and Howard (1971) and illustrated by Slee (2006) are powerful enough to allow for greater insights and potentially greater brownfield policy solutions. The application of GMCR to environmental conflicts is not new and has been shown to model both the GDU conflict mentioned previously as well as the Elmira Uniroyal conflict quite well (Fraser and Hipel, 1984; Fang, et al., 1993; Znotinas and Hipel, 1979). Brownfield redevelopment projects provide an opportunity to incorporate GMCR techniques to a pressing environmental, economic and social issue. Moreover, attitudes and coalition analysis, defined in Chapters 3 and 2, respectively, for extending the GMCR methodology are valuable for providing insights into the strategic aspects of brownfield redevelopment and environmental management disputes.

4.5 Summary

The review of literature presented here shows the need for implementing strategic conflict analysis methods. Previous DSSs implemented in brownfields redevelopment have focused on quantitative methods using cardinal values and weights (Regan, et al., 2005; Sounderpandian, et. al, 2005). This approach has been successful for models that focus on economic or environmental data. However, there is a gap in the application of qualitative models to brownfield problems. In the next chapter, two brownfield conflicts will be examined through the application of GMCR.

5

Brownfield Conflict Resolution

5.1 Introduction

Systematic tools are useful for and have been applied to a myriad of environmental conflicts. One common tool that has been used in this area is multiple criteria decision analysis (MCDA) where various alternatives are measured against a set of weighted criteria. Hipel (1992) explored the application of multiple objective decision making to the Three Gorges Dam project while Rajabi, et al. (2001) examined the allocation of water resources in the Great Lakes-St. Lawrence region using MCDA. The Graph Model for Conflict Resolution (GMCR) also lends itself very well to the analysis of environmental conflicts. These conflicts, like many other negotiations, are made up of wide variety of decision makers (DMs) with separate agendas that a strategic decision support, like GMCR, is extremely useful for providing all involved with a clearer picture. Hipel, et al. (1997) describes the application of GMCR as an environmental conflict management tool and apply the framework to the Flathead River Dispute of 1988. Groundwater contamination (Fang, et al., 1993), sustainable development (Hamouda et al., 2004) and the implications of dam construction (Fraser and Hipel, 1984) have also been examined successfully using GMCR. Brownfield conflicts are analyzed in the following sections using the Graph Model for Conflict Resolution (GMCR) in order to find insights into the types of attitudes and actions that are needed to create resolutions that are satisfactory of all DMs.

5.2 Brownfield Conflicts

From the analysis of private brownfield redevelopment and in conversation with a brownfield expert in the City of Kitchener (Boutilier, 2007) brownfield negotiations are broken down into three central conflicts as shown in Fig. 5.1. Starting from the left and moving towards the right with time, the three conflicts are property acquisition, remediation planning and finally renovation. Each of the arrows illustrates the involvement of different decision makers in the process at different times. In the analysis that will follow, each of the three nodes will be analyzed using appropriate systems methodologies. The following case study of the Kaufman redevelopment, in section 5.3, is from the manuscript by Walker, et al. (2008).

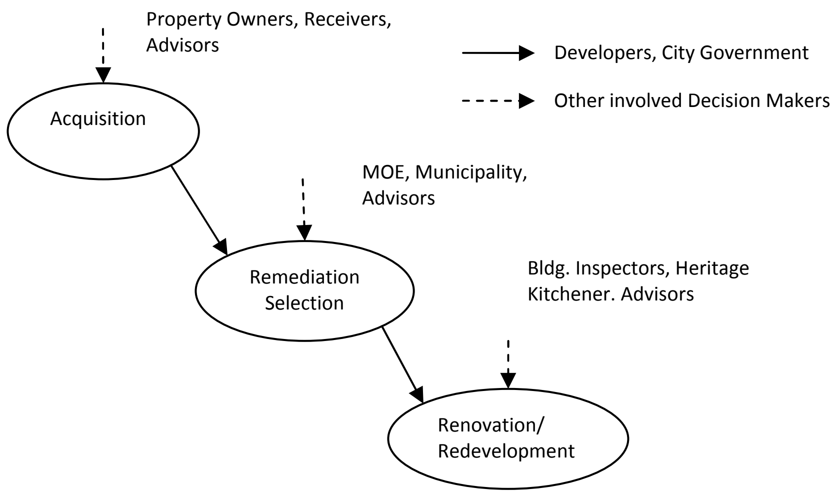


Figure 5.1. Series of conflicts in Kaufman renovation project

5.3 Kaufman Lofts

5.3.1 History of Kaufman Factory in Kitchener, Ontario, Canada

The site of the Kaufman Footwear factory lies at the corner of King Street and Victoria Street in downtown Kitchener. A tall imposing building, the factory is a symbol of the city’s downtown revitalization. Its large windows, designed to allow in maximum lighting during the day, and its high roofline reflect a bygone era of industrial architecture. This building has been a prominent part of Kitchener’s urban landscape since its construction was completed in 1925.The structure was designed by Albert Kahn, an influential architect whose style and design methods greatly impacted industrial designs worldwide. The company that still bears his name was founded in 1895 and his work in Detroit on major automotive plants greatly influenced the face of the ‘Detroit renaissance' (AKA, 2007). By the time the building was constructed, Kahn had already established himself as a superior industrial architect and entrepreneur (Hildebrand, 1974).

Kaufman Footwear was established by Alfred Kaufman and his father Jacob in 1907. Their Kitchener factory opened in the city formerly referred to as Berlin in 1908 and construction on the facility was eventually completed in 1925. From its opening in 1908 until its closure in 2000, the Kaufman factory was the workplace of thousands of members of the community, employing as many as 1600 people in 1996 (Pender, 2004; Globe and Mail, 2005). The Sorel shoe, introduced in 1960, was one of the most well-known products produced by the Kaufman brand, coinciding with a period of great prosperity for the company. In the 1990s, however, the company struggled financially and by 1998 the first of many layoffs began at Kaufman due to poor sales. Finally, in 2000 Kaufman Footwear went bankrupt and the property went into the receivership of Ernst and Young (Pender, 2004; University of Waterloo, 2005).

At the time of Kaufman's bankruptcy, the City of Kitchener became aware of contamination beneath the property. Due to the production of fire safety boots on the site, liquid naphthalene was stored onsite in an underground tank. In the 1990s, when the tank was removed, employees found that the tank had many holes, the ground smelled of naphthalene and that the soil was stained. Although effort was made by Kaufman's employees to remove the stained soil, an appropriate cleanup was not completed and a plume of naphthalene was left below the property (OCETA, 2007).

5.3.2 Acquisition Conflict

The first conflict node, as shown in Figure 5.1, is the acquisition conflict. In this conflict, one party is attempting to purchase the property as cheaply as possible while obtaining the most benefits possible from the local government. The property owner, meanwhile, is trying to earn as high a profit as possible.

5.3.3 Graph Model of the Acquisition Conflict

The first conflict within a private brownfield renovation is the acquisition of the brownfield property by a third party, usually a developer (D) or real estate company. As mentioned previously, the other two DMs would be the property owner (PO) or receiver and the city government (CG) whose job it is to entice the buyer into purchasing the property. The three DMs and their respective options are displayed in Table 5.1.

Table 5.1. Decision Makers, Options and States in the Acquisition Conflict

PO	1. Sell High	N	Y	N	N	Y	N	N	Y	N	N	Y	N	-/N
	2. Sell Low	N	N	Y	N	N	Y	N	N	Y	N	N	Y	-/N
	3. Walk	N	N	N	N	N	N	N	N	N	N	N	N	-/Y
CG	4. Incentives	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	-
D	5. Buy	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N/-
	6. Walk	N	N	N	N	N	N	N	N	N	N	N	N	Y/-
	State ID	1	2	3	4	5	6	7	8	9	10	11	12	13

From Table 5.1, it can be seen that there are three DMs with a total of six options and thus a total 2^6 possible states each represented with Y/N notation. The “Y” or “N” in each column represents that the option has or has not been taken, respectively. For example, at state 8, PO elects to ‘Sell High’ but not ‘Sell Low’ or ‘Walk’, CG does not offer ‘incentives’ and D decides to ‘Buy’ and not ‘Walk’. Due to the mutual exclusiveness of some of the options, there are a large number of infeasible states. This means that both of these DMs can only choose one option at a time. For example, PO can choose to either sell high or sell low and not both options simultaneously. An additional notable feature of the options listed here is that both D and PO have the ability to leave the conflict by walking away from negotiations, as seen in options 3 and 6, labeled ‘walk’. When this option is taken the conflict moves to state 13. At this state, it does not matter whether the PO or D have selected the option only that the negotiation has broken down. Additionally, at state 13, the actions of CG have no impact. A move of this type is referred to as a common move as both DMs can unilaterally move the conflict to the same state. For the sake of this conflict, this common move is irreversible as it is assumed that if one party ‘walks’, the negotiations have ended. Within this conflict model, this common move is considered to be one-way in that after a DM has walked away from the negotiations, they cannot return. Thus as PO and D haggle about the price and whether or not to make a deal for the ownership of the property either DM can independently end the conflict. As this move is one-way, it is represented by a unidirectional arrow in Figure 5.2.

Following the identification of all the feasible states in the conflict, a ranking of states based on a DM's given preferences is developed for all DMs in the given conflict. For each of the DMs the preferences are based on simple motivations, as follows. D is a person or corporation whose purpose is to make wise investments for financial gain. Thus, D prefers to purchase the property at low cost in order to maximize profit. PO may be different depending on the specific brownfield being studied. Regardless of who the owner of the brownfield property is, the aim of PO is to sell for as great a price as the market will bear. For the sake of this analysis, the potential costs have been broken down into 'sell high' and 'sell low'. These options could also be rewritten as 'sell above market value' or 'sell below market value'. Certainly, these options could be expanded further; however, for the sake of the analysis herein, the two options will suffice. The motivation of CG is to use local taxpayers' money as effectively as possible. Thus, an investment in incentives is useful only if it causes development to occur. The overriding motivation for CG is to ensure that some sort of agreement is reached between PO and D in order that the vacant property will be reused. Using these motivations, the state rankings were determined and listed in Table 2 where the states are ranked from most preferred on the left to least preferred on the right for which states contained within brackets are equally preferred. For example, for PO states 8 and 11 are equally preferred as they are in the same set of parentheses. These states are equally preferred because, as shown in Table 1, they both represent D purchasing the property at the higher price. PO does not care whether CG offers incentives, representing the difference between states 8 and 11, as they do not change the profit made by PO from selling at the higher price.

Table 5.2. Ranking of States

DM	State Rankings
PO	(8, 11), (1, 2, 4, 5, 7, 10), (3, 6, 13), (9, 12)
CG	(8, 9), (11, 12), (1, 2, 3, 7), (4, 5, 6, 10), 13
D	12, 9, 11, 10, 6, 5, (3, 4), (1, 2, 7, 13), 8

Equally preferred states are denoted by parentheses.

Using the option form of the conflict in Table 5.1, the movements of the DMs can be expressed as a directed graph. In a directed graph, the arrows represent the potential movements by the different DMs between the different nodes or states, as per the definition of GMCR. The different patterns of the arcs represent the different DMs who are responsible for the particular movement while the arrowheads denote whether the moves are reversible or irreversible. As noted earlier, the only irreversible move is the common move available to both PO and D to state 13. In Figure 5.2, an integrated directed graph is shown where all of the movements of all the DMs are shown simultaneously.

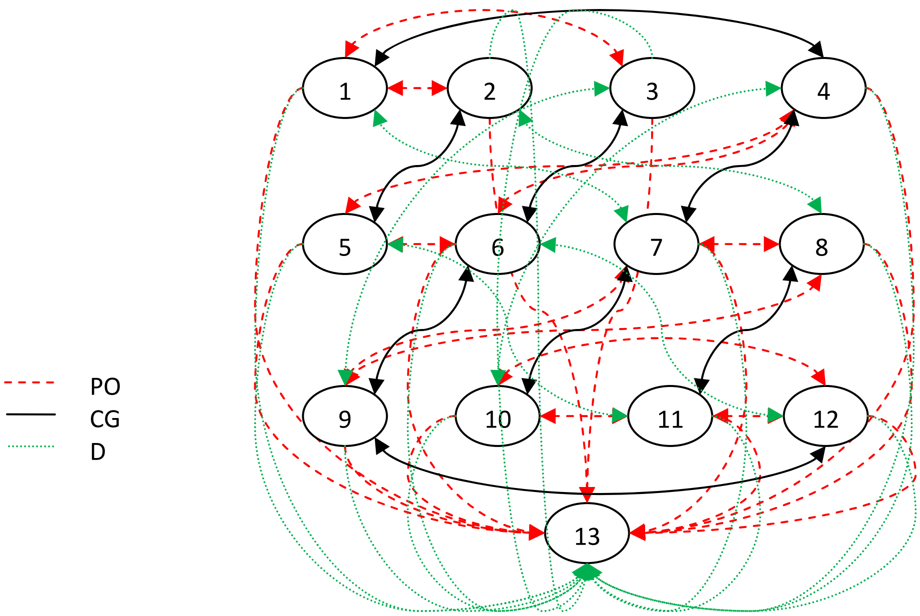


Figure. 5.2. Integrated directed graph of the acquisition conflict

Using the preferences rankings from Table 5.2 and the integrated directed graph in Figure 5.2, the acquisition conflict can be analyzed. The conflict is displayed in tableau form with each DM's ranking of states listed left to right from most to least preferred. Below each state are the UIs that the DM has from that state. As noted earlier, equally preferred states are in parenthesis within the state ranking. Using the solution concepts from Definitions 4 and 10 in Chapter 2, stabilities and, thus, equilibria can be determined as shown in Table 5.3.

Table 5.3. Tableau form of acquisition conflict

	X	E	E	E	X	X	E	X	X	X	E	X	X
	N	N	N	N	N	N	S	U	U	U	N	U	U
PO	(8	11)	(1	2	4	5	7	10)	(3	6	13)	(9	12)
							8	11	1, 2	4, 5		8, 7, 13	10, 11, 13
	N	N	S	S	N	N	N	N	U	U	U	U	N
CG	(8	9)	(11	12)	(1	2	3	7)	(4	5	6	10)	13
			8	9					1	2	3	7	
	N	N	N	N	S	S	S	S	N	N	N	N	U
D	12	9	11	10	6	5	(3	4)	(1	2	7	13)	8
					12	11	9	10					2, 13

E-Equilibrium state, X-Non-equilibrium state, N-Nash stable, S-Sequentially stable, U-unstable

Using these two solution concepts to equilibria found at states 1, 2, 4, 7, 11 and 13. Only one of these states corresponds to a situation where D buys and PO sells and, thus, the current model for this conflict contains only one equilibrium state that satisfies all the involved DMs. A telling sign is that none of the three DMs have unilateral improvements away from the status quo, preferring that the other DM(s) to make the first move towards a compromise. Thus, in order to achieve an outcome that benefits both the CG and D a new approach needs to be taken.

To illustrate the application of the solution concepts in Table 3, state 8 is examined. As for both PO and CG, $R^{+}_{i}(8) = \phi$ and thus, by Definition 4, state 8 is Nash stable for both DMs. For D, however, state 8 has two unilateral improvements as $R^{+}_{i}(8) = \{2, 13\}$. As $R^{+}_{CG}(2) = R^{+}_{CG}(13) = R^{+}_{PO}(2) = R^{+}_{PO}(13) = \phi$ neither PO nor CG have any credible moves that can sanction D and, hence, 8 is unstable (U) for D. As state 8 is stable for only two of the three DMs, state 8 is not at equilibrium and is marked with an X.

5.3.4 Attitudes in the acquisition conflict

The City of Kitchener, mentioned earlier, uses numerous enticements to encourage investment in local brownfields. Rebates are provided on fees for building permits related to the renovation or redevelopment of a brownfield property while developmental fees related to the need for increased infrastructure are waived. Additional assistance from the City of Kitchener comes in the form of Tax Incremental Financing, or TIF, whereby developers pay a reduced taxation rate after they have completed the renovation or redevelopment of the brownfield property. The amount saved is equal to the amount spent for remediation of the property and allows the developer an opportunity to recoup these costs up to the first one million dollars (CDN$). The final incentive offered by the City is that of a liaison between the City and the developer (Boutilier, 2007). The liaison helps the developer to prepare the property for its final use and deal with the various committees and organizations that are involved in property redevelopment. This incentive is one of the most important for potential developers as it allows the developer to work closely with the City and increases the likelihood that the project will be completed successfully, on time and with the least hassle.

In the previous analysis, it was assumed that each of the three DMs had 'rational attitudes', meaning that they had positive attitudes towards themselves and indifference towards all other DMs. In the analysis of the acquisition conflict, it is useful to determine what impact a change of attitudes would have on the equilibrium and on the potential moves that would be needed to move from the status quo to a desirable equilibrium or equilibria. As CG is responsible for trying to broker a deal between PO and D, it is feasible to suggest that the relationships between CG and PO or D impact the final outcome of the conflict. Using the attitude definitions created for GMCR by Inohara et al. (2007), three analyses are performed. In these analyses, the impact of CG holding positive attitudes towards either PO or D while holding indifferent attitudes towards itself are examined.

Table 5.4. Varying attitudes of CG

Original Analysis			
DM	PO	CG	D
PO	+	0	0
CG	0	+	0
D	0	0	+
Case 1			
DM	PO	CG	D
PO	+	0	0
CG	+	0	0
D	0	0	+
Case 2			
DM	PO	CG	D
PO	+	0	0
CG	0	0	+
D	0	0	+

The application of the attitudes in Table 5.4 alters the outcome of the conflict by changing which states are less or more preferred for CG at each state. The reachable lists at each state *s* for CG, $R_{CG}(s)$, remain the same however the UI lists, $R_{CG}^{+}(s)$, are replaced by the total relational reply lists, $TRR_{CG}(s)$. Since both PO and D have rational attitudes, the total relational reply lists of both DMs are equal to their UI lists. This can be written as $TRR_{D}(s) = R_{D}^{+}(s)$ and $TRR_{PO}(s) = R_{PO}^{+}(s)$, for cases 1 and 2. As explained in Definitions 21 through 26 in Chapter 3, the TRR lists consist of the states which satisfy the relational preferences held by a given DM, which are defined by the DMs attitudes towards the other DMs in the conflict. Thus, the set $TRR_{CG}(s)$ will change depending upon the attitudes being analyzed.

Table 5.5. TRR Lists for CG in Acquisition Conflict

S	1	2	3	4	5	6	7	8	9	10	11	12	13
$TRR_{CG}(s)$ – Case 1	1	2	3	4	5	6	7	8	9	10	11	12	13
$TRR_{CG}(s)$ – Case 2	1, 4	2, 5	3, 6	4	5	6	7, 10	8, 11	9, 12	10	11	12	13

In Table 5.5, the total relational reply lists are given for each state *s* in the conflict. In Case 1, there are no total relational replies for any of the states, except for the states themselves. This means that none of the reachable states are devoting preferences for CG with respect to PO and thus for CG all states are relational Nash stable. The change of attitudes on the part of CG greatly affects the potential movements that can be made and thus the various stabilities and equilibria. Applying the new total relational reply list for CG in Case 1, it can be seen that equilibria occur at states 1, 2, 4, 7, 11 and 13 and that each state is relational Nash stable for CG, as CG has no total relational replies. Although there are a high number of potential equilibria there are no unilateral movements away from state 1 that are not sanctioned. As there are no unsanctioned moves away from the status quo that correspond to the attitudes being analyzed in Case 1, the conflict would remain at the state 1. Thus, although there are six equilibria listed in Table 5.6, only state 1 represents the outcome of the conflict in this case.

Table 5.6. Tableau form of acquisition conflict – Case 1

	X	E	E	E	E	X	E	X	X	X	E	X	X
	RN	RN	RN	RN	RN	RN	RS	U	U	U	RN	U	U
PO	(8	11)	(1	2	4	5	7	10)	(3	6	13)	(9	12)
							8	11	1, 2	4, 5		8, 7, 13	10, 11, 13
	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN	RN
CG	(8	9)	(11	12)	(1	2	3	7)	(4	5	6	10)	13
	RN	RN	RN	RN	RS	U	RS	RS	RN	RN	RN	RN	U
D	12	9	11	10	6	5	(3	4)	(1	2	7	13)	8
					12	11	9	10					2, 13

E-Equilibrium state, X-Non-equilibrium state, RN-Relational Nash stable, RS-Relational Sequentially stable, U-unstable
Note: the states listed below the ranking of states for each DM represent the TRR lists for the given DM at the state, without including the state itself.

In Table 5.7 the attitudes TRR lists of CG in Case 2 are applied to the system. Under this analysis the two equilibria for the system are 11 and 13. Again, the relational solution concepts can be applied to determine the various stable states and system equilibria. For example, state 3 is a non-equilibrium state according to the relational stability concepts from Definitions 29 and 32. At state 3, PO has three total relational replies, as defined in Definition 26, to states 1, 2 and 3. Because PO holds rational attitudes, the TRR can be seen as comparable to a list of unilateral improvements with equally preferred states included. From states 1 and 2, D cannot sanction PO as $TRR_D(1)=1, TRR_D(2)=2$ and thus cannot move to sanction D. CG, however, has TRRs from states 1 and 2 such that $TRR_{CG}(1)=1,4,$ $TRR_{CG}(2)=2,5$, respectively. However, as PO relationally prefers 4 to 1 and 5 to 2 such that $4\,TRP_{PO}\,1$ and $5\,TRP_{PO}\,2$, CG cannot sanction PO and thus state 3 is unstable for PO. Using this methodology to systematically analyze each state`s equilibrium conditions are determined for the conflict.

Table 5.7. Tableau form of acquisition conflict – Case 2

	X	E	X	X	X	X	X	X	X	X	E	X	X
	RN	RN	RN	RN	RN	RN	RS	U	U	U	RN	U	U
PO	(8	11)	(1	2	4	5	7	10)	(3	6	13)	(9	12)
							8	11	1, 2	4, 5		8, 7, 13	10, 11, 13
	U	U	RN	RN	U	U	RS	U	RN	RN	RN	RN	RN
CG	(8	9)	(11	12)	(1	2	3	7)	(4	5	6	10)	13
	11	12			4	5	6	10					
	RN	RN	RN	RN	RS	U	RS	U	RN	RN	RN	RN	U
D	12	9	11	10	6	5	(3	4)	(1	2	7	13)	8
					12	11	9	10					2, 13

E-Equilibrium state, X-Non-equilibrium state, RN-Relational Nash stable, RS-Relational Sequentially stable, U-unstable
Note: the states listed below the ranking of states for each DM represent the TRR lists for the given DM at the state

Since CG has a total relational reply from state 1, the status quo is no longer an equilibrium state. Following the unilateral improvements made by each DM the conflict moves to state 11 where CG offers enticements, PO sells at a high price and D purchases the property.

Figure 3 shows the moves made by the three DMs to get from state 1 to state 11. As can be seen, CG first moves the conflict from state 1, the status quo where no options are selected to state 4 by offering incentives, D moves the dispute from 4 to 10 by agreeing to buy in the area with incentives offered and, finally, PO moves the conflict from state 10 to 11 by putting the property up for sale to the enticed D.

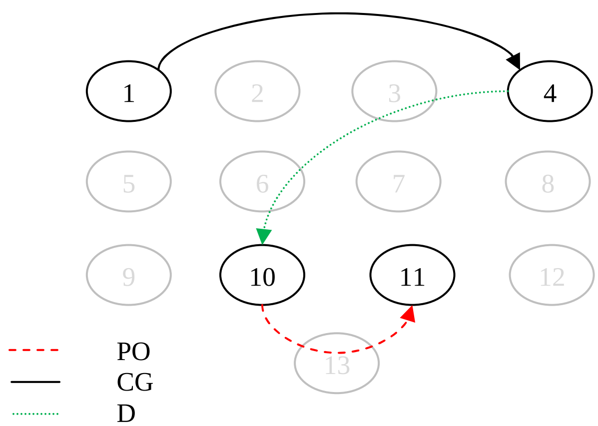


Figure 5.3. Movements leading to the equilibrium in Case 2

The conclusion of this analysis is that a movement by CG that is counter to its own preferences and rational preferences in the short term can in the long run cause the conflict to move to a more preferred state. First, CG offers incentives which attract interest from purchasers allowing a deal to occur between PO and D. As noted by Inohara et al. (2007), when DMs make moves that are counter to their own immediate gain, they may lead the conflict to an outcome that is more suitable for all involved. Further, the application of positive attitudes to CG are accurate as they represent CG's willingness to offer a staff member and numerous other incentives in order to foster a deal.

The second conflict in the series of conflicts needed to continue the renovation or redevelopment project is that of determining the appropriate remediation method. The selection of the appropriate remediation method in a brownfield project depends upon the physical conditions as well as financial and legal limitations. Within the province of Ontario, obtaining a Record of Site Condition (RSC) for a brownfield property is the main goal of any remediation project (MOE, 2007). The following sections examine the conflicts involved with the remediation selection within the context of the Kaufman renovation.

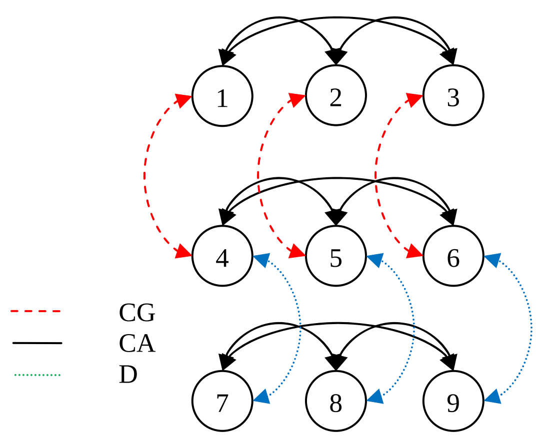
5.3.5 Site Division

During the renovation of the Kaufman property a site division was necessary in order to undertake the needed remediation. Although site division is not a necessary step in all renovations or redevelopments on a brownfield property, it is useful to analyze the conflict for completeness here. The Kaufman property purchased by Kimshaw Holdings in 2004 comprises a large land area in downtown Kitchener. The original factory building, to be renovated for use as lofts, sits at the corner of King and Victoria streets and faces towards King Street. Behind the original factory is a large piece of land that borders on Victoria Street and formerly held the offending storage tank. The goal of dividing this property into two pieces was to place all of the contamination on a property behind the building that would be remediated while the renovation took place. Only one piece of the original factory sat above contaminated soil and thus, as soon as that piece was remediated, the building could be inhabited, provided that the property was divided. In order that all of the contamination be maintained on the one property and thus only one record of site condition (RSC) was necessary a horizontal severance was needed (XCG, 2004). Such severances are special in the case of brownfield projects and are more often applied to instances including dividing land underground for city use in the building of subway lines (Buttigieg, 2007). Horizontal severances have been seen as a potentially negative planning tool by the Ministry of the Environment (MOE) which is concerned that it could be used by DMs to step away from their responsibility to remediate contaminated subsurface soil by relieving the property owner or developer of ownership of the contamination (MOE, 2007). Others argue that the use of such a planning tool could provide flexible solutions for a myriad of brownfield conflicts (Buttigieg, 2007).

Table 5.8. Options in site division conflict

Decision Maker	Options									
Committee of Adjustment (CA)	Accept	Y	N	N	Y	N	N	Y	N	N
	Accept with conditions	N	Y	N	N	Y	N	N	Y	N
	Reject	N	N	Y	N	N	Y	N	N	Y
City Planner (CG)	Advise D	N	N	N	Y	Y	Y	Y	Y	Y
Developer (D)	Accept advice	-	-	-	N	N	N	Y	Y	Y
State ID		1	2	3	4	5	6	7	8	9

The option form of the site division conflict is shown in Table 5.8. The Committee of Adjustment (CA) is made up of former city representatives, lawyers and real estate experts with a vast knowledge of the City's bylaws. CA's responsibility is to determine whether the subdivision of a property into two or three sections satisfies local bylaws and the planning act (City of Kitchener, 2006a). At this stage, a City planner, representing CG, works with D to develop an appropriate site division plan. In the options shown above, it is assumed that CA must choose one of the three options and that CG can advise D on the appropriate site division plan and that D can accept this advice or not. For this analysis, it is assumed that CG has a firm grasp as to what types of plans CA will or will not accept. Using this assumption about the knowledge of CG and the option form in Table 8, the graph model of the conflict is formed as depicted in Figure 5.4.



P_{CA}={(7, 6, 3), 8, (2, 5), (1, 4), 9}
P_{CG}={1, 7, 4, 2, 8, 5, (3, 6, 9)}
P_D={(1, 4, 7), (2, 5, 8), (3, 6, 9)}

Figure 5.4. Graph model for site division conflict

In Figure 5.4, the arrows represent the strategic moves and countermoves available to each of the DMs, while the sets of states below the graph represent a ranking of states from most to least preferred for each of the DMs. The assumption behind the ranking of states for CA is that if CG offers advice and D follows this advice, CA is likely to approve the plan. However, if CG does not offer advice or D does not follow the given advice, CA will prefer not to approve the plan or to approve with recommendations. CG's preference is that the plan be approved and that if they advise D that the plan will be accepted. D's preference ranking is simply a preference that the plan be approved, accepted with conditions, or rejected respectively. From information in Figure 5.4, the conflict can be analyzed in tableau form.

Table 5.9. Tableau form of site division conflict

	E	E	E	X	X	X	X	X	X
	N	N	N	U	U	U	U	U	U
CA	(7	6	3)	8	(2	5)	(1	4)	9
				7	3	6	2, 3	5, 6	8, 7
	N	N	U	N	N	S	N	N	N
CG	1	7	4	2	8	5	(3	6	9)
			1			2			
	N	N	N	N	N	N	N	N	N
D	(1	4	7)	(2	5	8)	(3	6	9)

E-Equilibrium state, X-Non-equilibrium state, N- Nash stable, S- Sequentially stable, U-unstable

After performing a simple analysis of the conflict, it can be seen that equilibria exist at states 3, 6 and 7. These correspond to the states where CA rejects the application and CG does not offer advice, CA rejects the application and CG offers advice and D does not take the advice and the case where CA accepts the application that is advised by CG and D accepts the advice. These states are logical equilibria, as they are the most preferred states of CA, the committee who's decision are responsible for the final outcome. Given that these states represent the stable equilibria, it is in CG's and D's best interest to work together to create a plan that will be approved by CA, based on the assumptions of this model.

5.3.6 Remediation Selection

In the purchase and redevelopment of a brownfield property one of the main financial burdens is that of remediation of the contaminated soil. In the Province of

Ontario, it is the duty of the property owner to decontaminate the offending soil according to either generic levels provided by the MOE or by a remediation plan, referred to as a site-specific risk assessment (SSRA). The goal of the SSRA is to outline what exposure risk exists on the property and to point out what areas of the property need to be remediated, while generic levels refer to levels of contaminant concentration that are deemed acceptable. In general, all of the DMs involved in a brownfield project would prefer that the property is decontaminated to generic levels set by the MOE. However, sometimes such a cleanup is not feasible, whether it be for financial or physical reasons. In such cases, a SSRA is undertaken to determine whether the contaminants that are present pose any threat to the environment or public health (MOE, 1996).

The goal for the developer of this remediation process is to obtain an RSC which allows the developer to renovate or redevelop the property towards its final use. MOE provides a road map of the conflicts involved in this process (MOE, 2004). An adapted version of the flow diagram is shown in Figure 5.5.

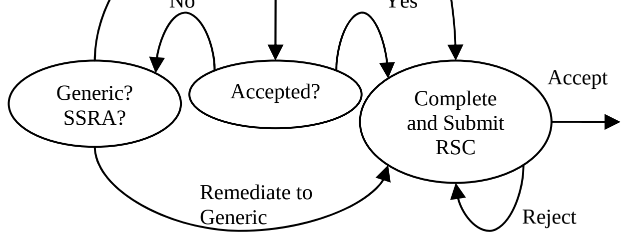


Figure 5.5. RSC process (MOE, 1996)

As can be seen in Figure 5.5, obtaining an RSC by performing an SSRA instead of remediating to generic standards is a task that involves the preparation of an SSRA and additional approvals. For the Kaufman Loft project, the King Street property that includes the lofts themselves needed an SSRA, while the Victoria Street property was remediated to generic MOE contaminant guidelines. One reason for the SSRA on the King St. property was the presence of Naphtha contamination below the corner of the building, the other was to ensure that the presence of other contaminants were not harmful to building workers or future residents. As in the previous conflict of site division, the MOE does not have a specific preference as to whether to accept or reject either the SSRA or the RSC. However, the MOE does want the SSRA to account for any potential harm to both human health and the environment, as this is part of the mandate of the MOE. Thus, if the SSRA or its accompanying remediation plan is deficient, it is certain to be rejected. Additionally, the MOE expects "…that the large majority of site remediations will be based on generic criteria…", (MOE, 1996) putting pressure on D to remediate to a generic standard, if possible.

5.3.7 Renovation/Redevelopment

The final conflict node in the brownfield redevelopment process depicted in Figure 1 is that of the renovation of the building itself. For the Kaufman renovation, the conflict could be seen as involving D and two other DMs consisting of Heritage Kitchener and the city building inspectors. The building inspectors ensure that work is done properly to ensure the safety of future residents of the lofts. Any conflicts between D and the inspectors would be dependent upon the work of the construction contractor hired by D. In the case of the Kaufman renovation, Kimshaw Holdings had no such conflicts with building inspectors from the City of Kitchener. The second DM, however, was involved in a conflict with Kimshaw Holdings during the Kaufman renovation. Heritage Kitchener is a group that "advises Council on matters involving conservation of publicly and privately owned heritage resources within Kitchener and is the City's local architectural conservation advisory committee as defined in the Ontario Heritage Act" (City of Kitchener, 2006b). As such, Heritage Kitchener (HK) approves or rejects plans and sends its recommendations to City council. The vision of HK has been one of conservation as opposed to preservation. Thus, for the Kaufman phase the goal was to conserve some of the key architectural features of the building, in keeping with the work of the building's architect; renowned industrial architect Albert Kahn. One key element of Kahn's work was that of uniform lighting, achieved through the use of large windows (AKA, 2003).

Another important architectural element is that of the high roof lines prominent in so many of Kahn's works.

In the renovation of the Kaufman building, the original intended renovation developed by architects for Kimshaw Holdings, had a greatly modified roofline that was not in keeping with the original architecture of the building. If one labels this unsatisfactory plan 'A' and an acceptable plan which does follow the guidelines of Heritage Kitchener 'B', the conflict in option form is shown in Table 5.10.

Table 5.10. Option form of renovation conflict

DM	Option				
D	A	Y	N	Y	N
	B	N	Y	N	Y
HK	Approve	Y	Y	N	N
	Reject	N	N	Y	Y
State ID		1	2	3	4

Taking the states from the option form shown in Table 5.10, the ranking of states is determined and shown in Table 5.11. The main difficulty for D within this process is that it may not know the preferences of HK. For the case of the Kaufman renovation, city planners helped Kimshaw Holdings come up with an alternative to the original plan in order to better satisfy the desires of HK. To demonstrate the importance that misperception has on the outcome of the conflict, a hypergame will be analyzed. Wang et al. (1988), defines a hypergame as a conflict where one or more DMs have a misunderstanding or misperception of the conflict. When performing sensitivity analyses of a conflict it is common to employ hypergames to analyze situations where DMs are unaware of potential options, DMs or changes in attitudes. To analyze a conflict with misunderstanding, one must posit what crucial information is misinterpreted or misunderstood.

Table 5.11. Preference rankings as seen by D and HK

DM	Preference ranking as seen by HK
D	1 > 2 > (3,4)
HK	2 > 3 > (4,1)
DM	**Preference ranking as seen by D**
D	1 > 2 > (3,4)
HK	(1, 2, 3, 4)

In the first-level hypergame proposed here, D is unaware of HKs preferences and, thus, in D's conflict HK prefers all four states equally. In HK's conflict, HK is aware only that D prefers its plan to be approved. In the hypergame, the conflicts are modeled with respect to the views of D and HK. States that are equilibrium for both conflicts are deemed to be overall equilibria and thus equilibrium results for the overall hypergame. As can be seen from Table 5.12, the only overall equilibrium that occurs is that of state 3 where D chooses the unsatisfactory plan 'A' and HK rejects it. This simple example using a hypergame in GMCR illustrates how misperception and misunderstanding can manifest themselves and sidetrack negotiations between D and HK.

Table 5.12. Hypergame in the renovation conflict

Overall EQ	X	X	E	X
D's EQ	E	X	E	E
Stab.	R	U	R	R
D	1	2	(3	4)
UIs		1		
Stab.	R	R	R	R
HK	(1	2	3	4)
UIs	-	-	-	-

HK's EQ	X	E	E	X
Stab.	R	R	R	R
D	(1	2)	(3	4)
UIs	-	-	-	-
Stab.	R	R	U	U
HK	2	3	(4	1)
UIs			2	3

On the other hand, if the DMs are aware of each other's preferences, the outcome is much different. The lower conflict tableau in Table 5.12 represents the case where both DMs are aware of each other's preferences and is analyzed to the equilibria at states 2 and 3. These two outcomes correspond to HK approving plan B or rejecting plan A. The essential difference here is that D would be aware of which outcome is likely to be approved and would thus choose plan ‘B’. Information such as this confirms one of the many useful roles that the city planners undertake as part of their incentives towards brownfield redevelopment and renovation and illustrates the need for co-operation between D and CG throughout all of the conflicts in the brownfield renovation project.

5.3.8 Overall Conflict

The impact of the collaboration of developers and city planners to form positive relationships with positive developers in brownfield renovation and redevelopment has been displayed using GMCR in two key examples. The overall process can be represented as a single conflict which also reinforces the importance of positive interactions between the developer and the City. The conflict diagram in Figure 5.1 is condensed into a simpler, though less accurate, conflict diagram in Figure 5.6.

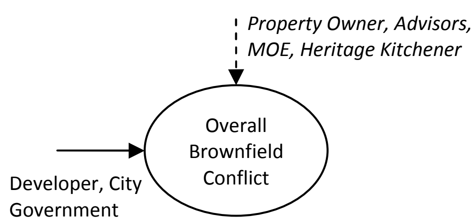


Figure 5.6. Generalized brownfield renovation conflict

Looking at the renovation of the Kaufman factory building into the useable residential space it is today as one large conflict with many DMs, it is not possible to develop one complete GMCR model which incorporates all of the elements of the three aforementioned conflicts. It is possible, however, to look at the costs and benefits associated by the actions taken by both the developer and city government. The main issues for the developer are the risk of liability associated with purchasing a contaminated property, the costs of remediation and the potential for future economic gain. For the city government, the issues include human health and social impacts of redeveloping a brownfield property as well as financial issues such as the potential for an increased tax base. For city governments, weighing the costs and benefits of these issues in the decision to aid developers with both incentives and guidance through the conflicts involved in the redevelopment is important to determining the best course of action.

Table 5.13. Advantages and disadvantages to CG for offering incentives

Incentive	Advantage	Disadvantage
Rebate on building permits	-Reduces costs to developer during final stage of renovation project	-Lost revenue to City government
Waiving of development fees	-Reduces costs to developer during final stage of renovation project	-Potential significant cost to the City government, especially if the renovation is lofts/apartments, etc. and requires a large increase in infrastructure
HR Incentive	-Reduce costs and time of project while improving relationship between the developer and the City government	-Requires an investment of City resources towards a private developer
TIF	-Allows developer to save money after completing the project -Incentive does not need to be paid until project is completed	-Temporary loss of tax revenue to the City

Table 5.13 briefly describes the advantages and disadvantages of the four incentives offered by the City of Waterloo for brownfield developments. The fourth incentive, Tax Incremental Financing (TIF), was not offered for the Kaufman renovation project as it was not in use in the City of Kitchener at the time the project was undertaken. However, TIF has come to be an important part of the City's brownfield strategy. By allowing developers to save on their taxes after redeveloping or renovating a brownfield property, the developer is able to recoup remediation costs without any risk to the City. The strength of this program has made it a common incentive in both Canada and the USA. The first three incentives: rebates on building permits, waiving of development fees and HR incentives are a part of the Kitchener EDGE program aimed at urban renewal within the core of downtown Kitchener. While offering rebates on building permits and waiving development fees may be a loss of revenue for the City, it is outweighed both by the eventual increase in tax revenue caused by the ultimately completed project and by the financial stability of the developer who is thus more likely to successfully complete the project. The third incentive, HR, is a key factor in building positive relationships between the City and the developer (City of Kitchener, 2006).

The decision made by a developer really comes down to the decision of whether or not to invest in a brownfield property as opposed to a greenfield property. As mentioned before, common issues include liability risk, remediation costs and financial potential. By offering financial incentives and assistance with the procedures involved in completing, the City of Kitchener greatly entices prospective developers to the region. The issue of liability risk is dependent upon the successful completion of a record of site condition (RSC) by the developer with the help of a qualified environmental consultant (MOE) and is out of the control of City governments. However, financial issues and zoning or property division issues that can keep developers from investing are well within the control of local governments. By allowing a city planner to work with the developer, the government/developer relationship becomes less adversarial as planners help the investor deal with the Committee of Adjustment and local interest groups, such as Heritage Kitchener. Certainly, observing the renovation of the Kaufman property as a large overall conflict, positive attitudes and working with developers to find better outcomes is an important step towards a successful renovation project.

5.3.9 Conclusions

The analysis of the key conflicts involved in the Kaufman renovation project illustrates the importance of positive attitudes and clear communication in brownfield renovation and redevelopment projects. By creating positive relationships with developers through financial incentive packages and guidance through the community's various committees and advisory boards, brownfield projects are more likely to come to a successful end. Work by the City of Kitchener to provide clear information to developers about the needs of the committee of adjustment and Heritage Kitchener has a definite impact on the ability of the developers to create successful projects. The application of GMCR to the conflicts involved in the renovation of the former Kaufman footwear project also shows that when multiple DMs have related interests, it is possible to create solutions that satisfy the majority of DMs involved.

The renovation of the Kaufman Shoe Company building in downtown Kitchener has been a social, environmental and financial success for both the developer and the City of Kitchener. It is the positive interaction of decision makers, as shown through illustrations with GMCR that has led to this outcome.

5.4 Eaton’s Lofts

A great amount of urban revitalization has occurred in the City of Kitchener as private developers have worked with the local government to redevelop vacant and unused properties and buildings. One of these properties, referred to as the Eaton’s Lofts, has been a subject of great interest to Kitchener residents. Unlike the successful renovation of the Kaufman factory, the Eaton’s lofts project has been marred by conflict between the developer and the tenants.

Located near the corner of King St. and Frederick St. in downtown Kitchener, the Eaton’s Lofts developed after the Eaton’s retailer left the downtown in the 1990’s. The property was developed by Loren Drotos and individual units sold for as much as $299,000 with parking spots selling for as high as $20,000. With the considerable amount of investment that residents put into living at the Eaton’s complex, the problems that followed the completion of the problem were devastating. The inability of the Drotos family, who owned the condominium and acted as the property’s private developer, to ensure that proper repairs were completed on the building and that asbestos was removed from the building before residents moved in resulted in bad publicity for loft-style developments within the City of Kitchener. In fact, it was during updates to the unfinished project ordered by Justice James Ramsey that asbestos was found putting a further snag in the completion of the Eaton’s Loft project. Although the property is not a brownfield property by USEPA definition, the difficulties in the completion of its redevelopment speak to the issues affronting all brownfield properties (Caldwell, 2007, 2007a, 2007b, 2007c).

5.4.1 Graph Model of the Eaton’s Loft Conflict

The Drotos family herein referred to as ‘the developers’ purchased the property that would be known as the Eaton’s Lofts with the goal of creating high value residential units in the heart of the City of Kitchener. Riding on the popularity of downtown living in the Kitchener-Waterloo area the Eaton’s Lofts was initially a very successful project until complaints from residence about the incomplete building and the eventual discovery of asbestos in the walls of the residence derailed the project significantly. The residents, who worked together to battle the developer in court, are seen as one DM referred to as ‘residents’. The DMs and options for this conflict are shown in tableau form for this conflict found in Table 5.14. Here, the developer (D) may either settle out of court or fight the residents in court to avoid paying damages and performing repairs while the residents (R) can either fight the developer through the court or not. The City's options are to help support residents in their legal battle through financial support or not.

Table 5.14 Eaton's Lofts conflict in option form

DM	Options	States							
Developer	1. Settle out of court	N	Y	N	Y	N	Y	N	Y
Residents	2. Legal action against developer	N	N	Y	Y	N	N	Y	Y
City Gov't	3. Support residents	N	N	N	N	Y	Y	Y	Y
State ID		0	1	2	3	4	5	6	7

In Table 5.14, the 3 possible options, available to the three DMs combine to make a total of sixteen possible states. Observing the total set of possible states infeasible states can be seen and removed. Any states where the developer both maintains a legal battle and decides to settle out court are obviously infeasible. These states are marked in bold in Table 5.14, removed from the conflict model, thus leaving twelve feasible states. The integrated graph model of the Eaton's Loft dispute is shown in Figure 5.7.

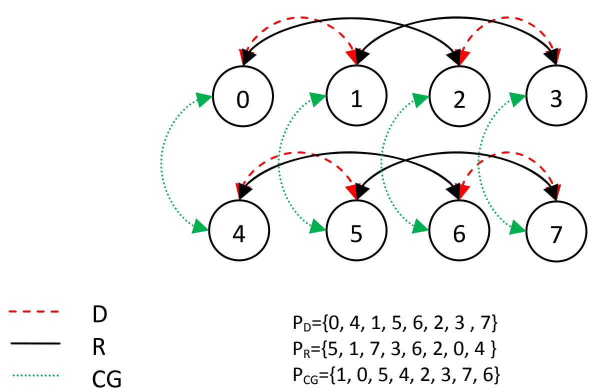


Figure 5.7. Integrated graph model for Eaton's Lofts conflict

Utilizing the integrated graph model in Figure 5.7 along with Nash and SEQ stability concepts it is possible to determine the stable outcomes of this conflict. In Table 5.15, the results of a simple stability analysis using Nash and SEQ is given in Tableau form for all 8 states. Here, it can be seen that the status quo state, state 0 is not an equilibrium state. However, the only equilibria occur at state 1 and state 2 where the developer settles out of court without legal action or assistance from the City or where the Residents take legal action and no one else makes any actions.

Table 5.15 Eaton's Lofts conflict in tableau form

DM	Stability							
Equilibria	X	X	E	X	X	E	X	X
D's stability	Nash	Nash	SEQ	SEQ	Nash	Nash	U	U
D's preferences	0	4	1	5	6	2	3	7
D's UIs			0	4			2	6
R's stability	Nash	Nash	SEQ	SEQ	Nash	Nash	U	U
R's Preferences	5	1	7	3	6	2	0	4
R's UIs			5	1			2	6
CG's stability	Nash	Nash	U	SEQ	Nash	Nash	U	U
CG's preferences	1	0	5	4	2	3	7	6
CG's UIs			1	0			3	2

The movements available to the DMs in this conflict from the status quo, state 0, move the conflict from state 0 to state 2 through a UI, $R_R^+(0) = \{2\}$. If CG makes a strategic disimprovement, one that can be shown through the application of attitudes, it is possible to reach a state that is more preferred by all DMs to state 2. Assuming CG's attitudes are such that $e_{CG\text{-}CG} = 0$ and $e_{CG\text{-}R} = +$, then the relational preferences and corresponding total relational replies are as shown in Table 5.16.

Table 5.16. Relational preferences

	Sets				States			
$RP_{CG\text{-}CG}(s)$	S	S	S	S	S	S	S	S
$RP_{CG\text{-}R}(s)$	1, 2, 3, 5, 6, 7	5	1, 3, 5, 6, 7	1, 5, 7	0, 1, 2, 3, 5, 6, 7	-	1, 3, 5, 7	1, 5
$TRP_{CG}(s)$	1, 2, 3, 5, 6, 7	5	1, 3, 5, 6, 7	1, 5, 7	0, 1, 2, 3, 5, 6, 7	-	1, 3, 5, 7	1, 5
$R_{CG}(s)$	4	5	6	7	0	1	2	3
$TRR_{CG}(s)$	-	5	6	7	0	-	-	-
s	0	1	2	3	4	5	6	7

In Table 5.17, the new analysis incorporating the aforementioned attitudes is given. In the presence of CG's attitudes, the new relational equilibrium for the conflict is state 6 as the conflict can now evolve further. First, R makes a move from state 0 to state

2 and next CG moves from state 2 to 6 where CG supports R in their legal battle against D. Although state 1 is much more preferred for all three DMs, supporting R against D is politically advantageous for CG.

Table 5.17. Eaton's Lofts conflict with attitudes in tableau form

DM	Stability							
Equilibria	X	X	X	X	E	X	X	X
D's stability	Nash	Nash	U	U	Nash	Nash	U	U
D's preferences	0	4	1	5	6	2	3	7
D's UIs			0	4			2	6
R's stability	Nash	Nash	SEQ	SEQ	Nash	Nash	U	U
R's Preferences	5	1	7	3	6	2	0	4
R's UIs			5	1			2	6
CG's stability	RSEQ	RNash	RNash	U	U	RSEQ	RNash	RNash
CG's preferences	1	0	5	4	2	3	7	6
CG's UIs	5			0	6	7		

5.4.2 Conclusions

Using GMCR it is possible to determine the actions that are needed and the types of attitudes necessary to produce these movements. By acting in a cooperative fashion towards R, it is possible that CG would act against their own preference not to spend in order to aid citizens, R.

5.5 Summary

The ability of the strategic decision support tool GMCR to illustrate the types of preferences, attitudes and actions that are needed to succeed in brownfield renovations is evident from the illustrations made in sections 5.3 and 5.4. With the knowledge of how DMs interact in these conflicts it may be possible to improve how brownfield regulations are structured to improve the way developers and local government collaborate in private brownfield renovations. In the following chapters, negotiations regarding the Kyoto Protocol are analyzed using systems methodologies.

6

Analysis of the Kyoto Protocol

6.1 Introduction

The application of systems tools to environmental conflicts is not limited to small scale problems such as individual negotiations regarding a contaminated property, the renovation of a former factory building or the management of water resources. Multiparty negotiations regarding the management of greenhouse gases through the Kyoto Protocol is modelled and analyzed using GMCR to determine the strategic moves and countermoves made by Russia in the negotiation of the protocol.

6.2 Kyoto Protocol

The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCC) which aims to reduce the emission of the gases that cause climate change. The protocol was first signed in 1997, with distinct climate goals set for 2008-2012 (United Nations, 2007). During the first time period of the protocol, the signing nations negotiated to reduce their CO_2 emissions to between -8% and +10% of 1990 levels. The protocol allows for the trading of emissions certificates by nations that exceed their reduction goals. Details of the trading system were negotiated after the initial signing date, with the goal of determining how the trading of emissions permits would work (Karas, 2006; OECD, 1999). Russia was one of the countries most interested in the exchange of emissions permits. At the time the treaty was signed, Russia was suffering economically due to the recent dissolution of the Soviet Union (Karas, 2006). As Russia was struggling to develop its capitalist-based industries and numerous factories were closed, it was apparent that Russia would have little trouble meeting the emissions guidelines it had negotiated for the protocol. In fact, due to the trading of emissions permits, Russia stood to make a significant windfall through its skilful negotiation of the protocol (Karas, 2006). However, the potential to profit in this excess of 'hot air', as some referred to it, was dependent on a suitable market in which to sell the permits (Karas, 2006; OECD, 1999). Many speculated that the United States of America (USA) would be the most likely buyer of these permits due to the drastic targets set by the protocol on the USA and its rank as the largest emitter of greenhouse gases (Karas, 2004; 2006).

At the onset of the protocol, in 1997, American President Bill Clinton was a champion of the Kyoto Protocol (CNN, 1997). However, shortly after Vice-President Gore and Senator Lieberman signed the protocol, the Senate voted 95-0 to not become party to the protocol if it did not include limits on emissions of developing nations as well as industrialized nations (CNN, 1997; US Senate Legislation & Records, 1997). President Clinton never attempted to have the protocol ratified by the Senate and in 2001, recently-elected President George W. Bush declared that the USA would not join without China's participation and questioned the science behind climate change (Whitehouse, 2001).

The USA's refusal to ratify the Kyoto Protocol affected Russia both positively and negatively (Babicker, et al., 2002; Karas, 2006). Without the USA's involvement, Russia became the largest emitter of greenhouse gases of the negotiating parties and whether the protocol would be put into force depended heavily on Russia (Babicker, et al., 2002). This was due to the protocol's stipulation that 55 nations producing at least 55% of the world's greenhouse gas emissions must ratify the Kyoto Protocol before it be put into force (Babicker, et al., 2002; United Nations, 2007). Russia was now in a strong bargaining position to draw positive incentives from parties that wished the protocol to be implemented (Karas, 2006). European nations, that had already signed the Kyoto Protocol and desired implementation, approached Russia with a plan to ease its entry into the World Trade Organization (WTO) (Babicker, et al., 2002; Reuters, 2004; Reuters, 2004a). It is reasonable to assume that Russia's eventual decision to ratify the protocol on September 30, 2004 was due not to environmental concerns stipulated by Russia's government but the potential for fiscal and political gain made from acting in coalition with members of the European Union (EU) (Babicker, et al., 2002; BBC, 2004; Karas, 2006). In the following sections, the key concepts of the Graph Model for Conflict

Resolution and a methodology for examining coalitions are applied to the Kyoto Protocol to show how Russia's ratification occurred with the intervention of the EU. The conflict between Russia, the United States and eventually the European Union, is analyzed in the following subsection, 6.3.

6.3 Kyoto Protocol Conflict Between Russia and The USA

Table 6.1. Option form of the Russia-USA Kyoto conflict

Decision Maker - Option	States			
USA – Ratify	N	Y	N	Y
Russia – Ratify	N	N	Y	Y
State ID	0	1	2	3

At the onset of this conflict there were only two DMs from Russia's point of view: Russia and the USA. Both the USA and Russia had the option of ratifying the protocol in this conflict. Option form, developed by Howard (Howard, 1971), shows that states are created from the simple combinations of yes (Y) and no (N) for each DM's given options. Writing the Kyoto protocol conflict between the USA and Russia in option form, there are four states, numbered 0 to 3 for this conflict as shown in Table 6.1.

Table 6.2. Normal form of the Russia-USA Kyoto conflict

	USA		
Russia	Options	R	D
	R	RR	RD
	D	DR	DD

A convenient way to write two-DM conflicts is using normal form, as shown in Table 6.2. This form is practical for displaying conflicts between two DMs and has been used before to analyze international conflicts. In this form, the structure of the game is altered such that both Russia and the USA have the mutually exclusive choices to either ratify (R) the protocol or decline (D). Each time both DMs choose an option, the result is referred to as a state. If both the USA and Russia, for example, chose to ratify the protocol, (R) then the resultant state would be RR as shown in the top left-hand corner of the Table 6.2. Again, there are four states in total, resulting from the combination of each DM's strategies.

6.3.1 Amicable Ratification

Table 6.3. Tableau form of the Russia-USA Kyoto Protocol Conflict

Equilibrium	Equil	X	Equil	X
USA Stability	Nash	U	Nash	U
USA	RR	RD	DD	DR
Unilateral Improvements		RR		DD
Russia Stability	Nash	U	Nash	U
Russia	RR	DR	DD	RD
Unilateral Improvements		RR		DD

Before complications with the Senate and Congress kept the USA from ratifying the protocol, President Clinton had positioned the USA to follow through with the protocol (CNN, 1997; US Senate Legislation & Records, 1997). Russia's ratification was important to the USA as China and developing nations were already unaccounted for in the protocol (CNN, 1997; US Senate Legislation & Records, 1997). As mentioned previously, Russia's ability to negotiate its' future emissions to 1990 levels left it with the potential for a surplus of emissions permits that could be sold to other nations. As the USA is the largest global emitter of greenhouses gases Russia desired that the USA ratify the protocol. Without the USA, the demand for emissions permits would drop significantly and thus the potential profit would also diminish (OECD, 1999). The Organization for Economic Cooperation and Development (OECD) estimated that without the USA, the total value of Russia's emissions permits could drop from $4.39B to $161M, a significant loss in profit (OECD, 1999). Thus, the ranking of states from most to least preferred for Russia was RR, DR, DD, RD and for the USA was RR, RD, DD, DR. Both DMs wanted to ratify the protocol with the other DM and not to ratify alone. Russia's unilateral moves, as shown in Fig.1, correspond to moves between the two rows meaning that Russia has unilateral moves from RR to DR and from RD to DD, while the USA's unilateral moves are represented as movements between the two columns meaning that the USA has unilateral moves from RR to RD and from DR to DD.

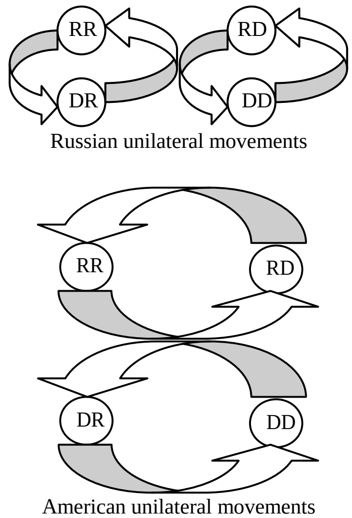


Figure 6.1. Unilateral movements of Russia and USA.

In Table 6.3, the conflict is displayed in the tableau format suggested by Fraser and Hipel (Fraser and Hipel, 1979; Fraser and Hipel, 1984) to illustrate the stable states and equilibriums. In tableau form, the states are listed in order of preference from left to right for each DM with any unilateral movements from the given state listed below that state for the particular DM. Any states that have no unilateral improvements for a given DM are Nash stable for that DM from Definition 7. If the state is Nash stable, sequentially stable or unstable; Nash, Seq or U are written above the given state, respectively. States that are stable for all DMs are marked Equil for equilibrium and all non-equilibrium states are denoted by an X.

Analyzing the stability of the states in the USA's preference ordering, it is observed that states RR and DD are Nash stable as both states satisfy Definition 7. DD is Nash stable for $USA \in N$, $DD \in S$ as $R^{+}_{USA}(DD) = \phi$. State RD is unstable for the USA as it does not satisfy either Definition 7 or 8. By

6.3.2 Changing Preferences of the USA

After the US Senate unanimously voted not to ratify the protocol, President Clinton faced a mounting struggle to promote the importance of the protocol for the remainder of his time in office (Karas, 2006; US Senate Legislation & Records, 1997). Newly elected President George W. Bush explained in 2001 that due to a lack of faith in the science and the legislation, the USA would not ratify the protocol (Whitehouse, 2001). This caused a rearrangement of the USA's preferences makes DD the only remaining equilibrium as shown in Table 6.4.

Table 6.4. Tableau form of 2nd Russia-USA Kyoto Protocol conflict

Equilibrium	Equil	X	X	X
USA Stability	Nash	Nash	U	U
USA	DD	RD	DR	RR
Unilateral Improvements			DD	RD
Russia Stability	Nash	Seq	Nash	U
Russia	RR	DR	DD	RD
Unilateral Improvements		RR		DD

Table 6.5. Option form of the expanded Kyoto Protocol conflict

DM	Option	States							
USA	Ratify	N	Y	N	Y	N	Y	N	Y
Russia	Ratify	N	N	Y	Y	N	N	Y	Y
EU	Entice Russia to Ratify	N	N	N	N	Y	Y	Y	Y
State IDs		0	1	2	3	4	5	6	7

During this period the conflict stayed at this new status quo, with new DMs moving into the dispute hoping to improve the chances of Russia ratifying the protocol (Karas, 2004; 2006). Whether or not Russia's delay in endorsing the protocol following USA's withdrawal was a strategic move to entice other nations to offer incentives for Russian ratification has been debated (Karas, 2006). Regardless of whether it was intended, Russia's delay in ratification drew notice from nations that had committed to Kyoto and wanted it to come into force.

6.3.3 The Introduction of the European Union to the Kyoto Protocol Conflict

While the United Nations pleaded with Russia to ratify the protocol, a large number of EU member countries made efforts to persuade Russia to support the common good by helping to bring the Kyoto Protocol into force (AFP, 2004; Karas, 2006; Reuters, 2004a). For Russia, the key reasons to join the protocol would be for its own political or fiscal gain (Karas, 2006). What began to entice Russia into ratifying the protocol was the move by the EU to help Russia move into the World Trade Organization (WTO) in exchange for Russian ratification (BBC, 2004; Karas, 2006; Reuters, 2004).

Thus, a new conflict was formed between USA, Russia and the European Union (EU). Table V displays the options of each DM as well as the list of all possible states in the conflict. The states have been renumbered and thus differ from those defined in Table 6.1 of subsection 6.2.

6.3.4 Preferences

The Russian and USA preferences match the ones assigned to them in the Section III, Subsection B where the USA prefers not to ratify the protocol. Recalling this, it is noted that Russia prefers to ratify if it does not ratify alone. This has been expanded to include a preference by Russia to ratify in the presence of EU incentives. As before the USA prefers not to ratify above all and it's ranking of states from most to least preferred is the ordered set 0, 4, 6, 2, 1, 5, 7, 3. Russia's ranking of preferences reflects its' previous ranking of states from Section III, Subsection B as the ordered set 7, 3, 6, 5, 4, 1, 0, 2. The EU's preference ranking reflects a desire that both the USA and Russia ratify without EU incentive and a preference that if neither the USA and RUS ratify that no incentive be given. Thus the EU's ordering of states is 3, 2, 1, 7, 6, 5, 0, 4.

6.3.5 Unilateral Movement and Improvement Lists

In Table 6.6 the unilateral movements for the USA, Russia and EU can be observed in the second, third and fourth columns while the improvements are displayed in columns five, six and seven respectively. With information about preferences from Subsection A and information regarding how the DMs can move between states from Table 6.6, a stability analysis can be undertaken.

Table 6.6. USA and Russia unilateral movements and improvements

State	R_{US}	R_{RUS}	R_{EU}	R^+_{US}	R^+_{RUS}	R^+_{EU}
0	1	2	4	--	--	--
1	0	3	5	0	3	--
2	3	0	6	--	0	--
3	2	1	7	2	--	--
4	5	6	0	--	6	0
5	4	7	1	4	7	1
6	7	4	2	--	--	2
7	6	5	3	6	--	3

Putting the conflict into tableau form, the dispute is analyzed for Nash and Sequential stability in Table 6.7. Below each state is a unilateral or coalition movement that the DM can move to. Above each state is either ‘Nash’, ‘Seq’ or ‘U’ to denote whether the states are Nash stable, sequentially stable or unstable. Above the top row of stability indicators is either E or X which represents whether the state is an equilibrium or not, respectively.

Table 6.7. Tableau form of the expanded Kyoto conflict

	E	X	E	X	X	X	X	X
	Nash	Nash	Nash	Nash	U	U	U	U
USA	0	4	6	2	1	5	7	3
					0	4	6	2
	Nash	Nash	Nash	U	U	Seq	Nash	U
Russia	7	3	6	5	4	1	0	2
				7	6	3		0
	Nash	Nash	Nash	Nash	Seq	U	Nash	U
EU	3	2	1	7	6	5	0	4
				3	2	1		0

As shown in Table 6.7, there are two equilibrium states: states 0 and 6. State 0 corresponds to the status quo where neither the USA nor Russia ratifies the protocol and the EU does not entice Russia’s ratification. This outcome is the starting point of this three DM conflict as the EU joined the conflict when both nations had not ratified. State 6, the second equilibrium state, corresponds to EU enticement and Russia ratifying without the USA. Although this is a more preferable state for both the EU and Russia it is unreachable in this conflict model because neither the EU, nor Russia nor the USA has a unilateral move away from state 0. Thus, when all three DMs act independently there is no feasible path away from the status quo. By using a coalition analysis a feasible path can be determined to illustrate the importance of collaboration between the EU and Russia in this conflict.

6.4 Coalition Analysis of the Kyoto Protocol Conflict

Coalitions form in conflicts as DMs work together to achieve a more desired state for all coalition members. Previously, a coalition analysis for the Kyoto protocol was carried out by the OECD using environmental and economic costs and benefits as the only factors (OECD, 1999). The results of this analysis showed that due to the high cost associated with environmental gain there was incentive for DMs to 'free-ride' by taking the environmental gains without any economic investment. The coalition model defined below incorporates political incentives to create a model that better reflects international negotiation.

Table 6.8. Coalition movements and improvements

State	$R_A(x)$	$R_A^{++}(x)$
0	2,4,6	6
1	3,5,7	3
2	0,4,6	--
3	1,5,7	--
4	0,2,6	6
5	1,3,7	3, 7
6	0,2,4	--
7	1,3,5	--

Table 6.9. Coalition Analysis in tableau form

	E	X	E	E	X	X	X	X
	CN	CN	CN	CN	U	U	U	U
USA	0	4	6	2	1	5	7	3
					0	4	6	2
A	**CN**	**CN**	**CN**	**CS**	**CS**	**U**	**CN**	**CN**
Russia	**7**	**3**	**6**	**5**	**4**	**1**	**0**	**2**
				3,7	**6**	**3,7**	**6**	
	CN	**CS**	**CN**	**CN**	**CN**	**CS**	**CN**	**U**
EU	**3**	**2**	**1**	**7**	**6**	**5**	**0**	**4**
			3			**3,7**	**6**	**6**

The coalition analysis in Table 6.9 uses CN to denote coalition Nash stability and CS to denote coalition sequential stability.

In order to analyze coalitions, a separate set of solution concepts are needed to determine coalition stability and associated equilibria. Kilgour, et al. (2001), developed the concepts of coalition stability and improvement, while Inohara and Hipel (2008a) defined coalition solution concepts for Nash, general metarational, symmetric metarational and sequential stability.

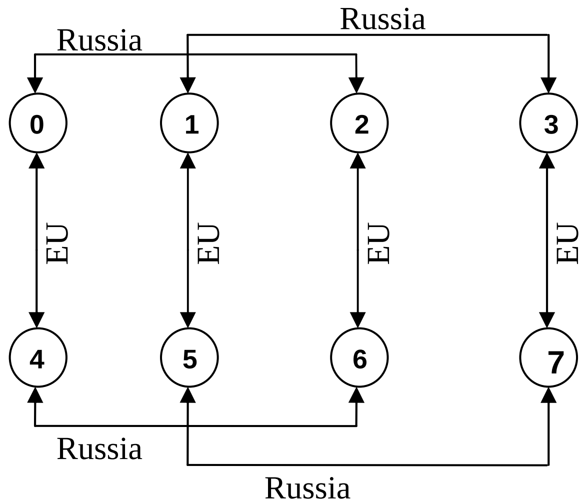


Figure 6.2. RUS and EU unilateral moves

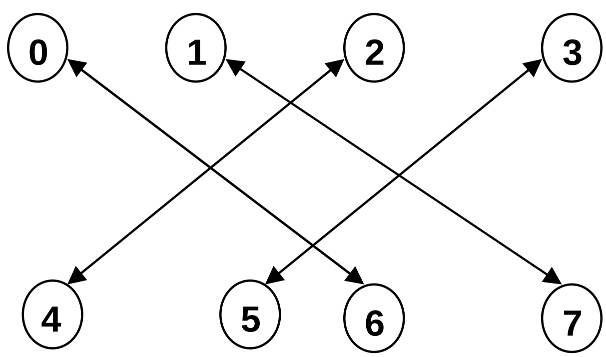


Figure 6.3. Coalition movements for Russia and EU

Using Definitions 1 through 6, 11 and 12 from Chapter 2, a set of unilateral and coalition improvements and movements can be developed for the case where Russia and EU form a coalition. This coalition, called Coalition A, has its own set of movements and improvements. From Definition 5 (i), at state 0, $R_{Russia}(0)$ =2 and $R_{EU}(0)$ =4, thus both 2 and 4 are coalition movements for Coalition A at 0. By induction in Definition 5 (ii), as $R_{Russia}(4) = R_{EU}(2)$ =6, 6 is also a coalition movement for Coalition A from 0. Thus, the complete set of unilateral movements for Coalition A from is defined as the set $R_A(0) = \{2,4,6\}$. From this list of movements, a set of coalition improvements as defined by Definition 11 are developed. As $6 \succ_{Russia,EU} 0$ while $2 \succ_{EU} 0$, $0 \succ_{Russia} 2$ and $4 \succ_{Russia} 0$, $0 \succ_{EU} 4$

the only coalition improvement for Coalition A from 0 is 6. Applying this methodology to set of states *S* a set of coalition movements and improvements are created in Table 6.8.

Using the Russia-EU coalition A there are now three equilibriums 0, 2 and 6 which represent the status quo, the state where Russia ratifies alone while the EU does not offer an incentive and where Russia ratifies while the EU does offer an incentive, respectively.

Observing Figures 6.2 and 6.3, it can be seen that the formation of Coalition A creates a set of coalition movements that allows the EU and Russia to move between states in cooperative ways.

Using these new movements to move to a mutually beneficial state, EU and Russia can move from the status quo at state 0 to state 6 where the EU offers the incentive and Russia ratifies the protocol. This move would be impossible without the creation of a stable coalition as seen in Figure 6.4.

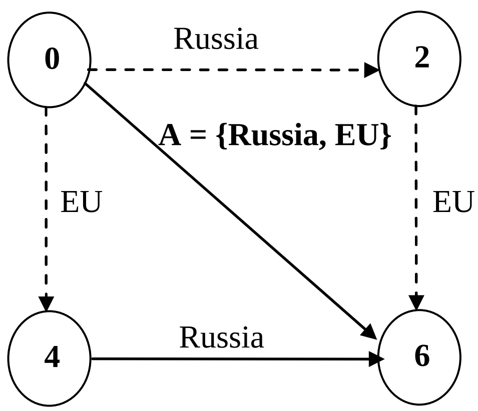


Fig. 6.4. State evolution through coalition move
The coalition improvement is from 0 to 6. Infeasible steps are marked with a dashed arrow. Russia is denoted as RUS.

This cooperative move allows the conflict to move from a state that was at equilibrium previously and move to a more preferred equilibrium state through an equilibrium jump. Equilibrium jumps, as defined by Kilgour, et al. (2001), are an important feature of coalition analysis which allows decision analysts to see the immediate advantage to all DMs upon the formation of a coalition.

6.5 Summary

As illustrated in the Kyoto Protocol conflict, the formation of coalitions between DMs can lead to positive results that may otherwise have not occurred. In the case of Kyoto Protocol negotiations, a resolution that ensured Russian ratification of the Kyoto Protocol in spite of USA withdrawal can be attributed to the formation of a Russia-EU coalition where both DMs worked together to move to a more desired equilibrium. The coalition methodologies applied here illustrate the importance of international cooperation in the area of energy and environmental policy as well as the importance of coalition analysis in conflict analysis. Such a systems methodology can be applied to future environmental conflict to aid decision makers in making informed strategic decisions.

7

Conclusions

In the preceding chapters, the conflict analysis methodology, the Graph Model for Conflict Resolution (GMCR), and associated coalition definitions are given, and GMCR is extended to include attitudes and applications to the fields of brownfield redevelopment and environmental management, providing analytical insight for brownfield negotiations. In Chapter 2, a detailed explanation of the graph model and coalition analysis is provided. Chapter 3 is focused on attitudes as defined within the framework of GMCR, accounting for variation within situations of a decision maker's (DM's) action motivated solely by positive self-interest and indifference towards fellow DMs. Brownfield decision models, indicators of social, environmental and economic brownfield presence and renewal, as well as characteristics of successful remediation are examined in Chapter 4. Using this literature review, a successful implementation of the GMCR decision support tool is presented in Chapter 5.

The methodologies defined in Chapters 2 and 3 are applied to brownfield redevelopment conflicts, and an international environmental management dispute in Chapters 5 and 6. The application of the methodologies developed in Chapters 2 and 3 to brownfield redevelopment demonstrates that an understanding of coalitions and attitudes improves an eventual outcome with respect to property acquisition, remediation and redevelopment of brownfields for all involved stakeholders. In Chapters 6, coalitions are applied to a larger-scale multinational conflict, illustrating the breadth of application of DM's attitudes and coalition formation.

7.1 Brownfield Redevelopment

Brownfield conflicts are examined with respect to the current state of research and the application of conflict analysis methodologies to the issue of redevelopment in Chapters 4 and 5. The Chapter 4 overview summarizes literature in the areas of governmental regulation, ecological indices, human health, finances and social justice, contrasting the impact of brownfield presence and redevelopment on the urban landscape. Whereas Chapter 5 outlines the impact of various strategies, preferences, attitudes and coalitions on the outcome of existing brownfield problems, Chapter 4 provides a sociocultural basis for this research as studied by economists, environmentalists, urban planners and scientists.

The application of conflict methodologies to brownfield redevelopment is an analytical tool for examining relationships among decision makers in the three stages of private brownfield redevelopment: acquisition, remediation selection, and redevelopment. Chapter 5's implementation of GMCR and attitudes within the context of a property acquisition conflict demonstrates an increase in long-term brownfield redevelopment for a city when the city government decides against immediate gain in holding an indifferent attitude towards itself and a positive attitude towards the developer. Additional analysis of seller attitudes reveals that when the seller and city governmental preferences are significantly divergent, the application of attitudes cannot overcome their player-focussed preference structures towards a brownfield remediation conflict resolution.

When formulating a remediation strategy, environmental contractors will determine acceptable contaminant levels on the brownfield site. Ontario Ministry of the Environment (MOE) guidelines ideally suggest generic standards which are independent of property for remediation of brownfields. However, in some circumstances remediating to the generic standards is physically or financially infeasible. In this case, environmental contractors will provide a site specific risk assessment (SSRA) to determine the risk of exposure to adults and children living on an affected property and perform remediation to the most relevant level of sensitivity based on proposed land use. The negotiations involved in remediation, including property severance, benefit from the inclusion of knowledge provided by forming coalitions with city planners, as noted in Chapter 5.

After the environmental risk assessment, the redevelopment construction includes interactions between developers, oversight committees, and city planners. In the case of the redevelopment of historic buildings in the City of Kitchener, the oversight committee is Heritage Kitchener. By forming positive relationships with city planners, as shown through the applications of attitudes and coalitions, who work in partnership with committees such as Heritage Kitchener, developers can make adjustments to redevelopment plans and avoid conflict. Within GMCR, a hypergame is used to show the repercussions that could occur if developers choose not to form positive working relationships with city officials to ease the approvals processes.

The post-development conflict, also analyzed in Chapter 5, reveals the problem that city officials can find themselves in after a project is completed. Although cities may wish to support developers whose tax dollars provide income to the community, in cases where developers have not lived up to their contracts it is the duty of the local government to protect its citizens. Within Chapter 5, the positive attitudes that local government must hold towards its citizens and the positive self-interest held by the developer are examined and the resultant actions of the city and developer are explained using these attitudes in the case study of the Eaton’s Lofts in downtown Kitchener, Ontario.

7.2 Main Contribution of Thesis

The examination of brownfield conflict through the application of strategic conflict analysis tools represents a stark contrast to the economic and environmental decision tools used throughout the field of brownfield redevelopment. As with GMCR’s application to brownfield and environmental management problems within this thesis, previous applications of the graph model to environmental conflicts such as the Elmira groundwater conflict (Fraser and Hipel, 1984) and the Garrison Diversion Unit (Fang, et al., 1993) have proven successful in providing insights into why certain outcomes have occurred in this important subset of systems problems. The application of the graph model to the area of brownfield redevelopment projects illustrates the importance of the relationship between the developer and the local government. When attitudes are positive, such that information is shared between DMs or when coalitions are formed so that actions can be made in conjunction with each coalition member, developers and local governments are able to reach positive win-win outcomes that satisfy the developers, local government and residents of the city.

The implementation of attitudes within GMCR represents a significant contribution to the theory of strategic conflict analysis. Through the use of attitudes, non-regular analyses can be undertaken without the necessity of rearranging a DM's preferences, thus avoiding errors in the determination of new preferences while still allowing for a greater amount of insight and knowledge to be taken from the decision model. The application of GMCR to the conflicts within the analysis of the Kaufman Lofts redevelopment in Kitchener, Ontario illustrates how DMs' attitudes can have significant impacts upon the final outcome of a conflict. In the analysis of brownfield conflicts, attitudes are applied through the framework of GMCR to illustrate how when local governments act with positive attitudes towards developers throughout the three steps of brownfield reuse outline in Chapter 5.

7.3. Future Research

The formal modelling of attitudes is a strong systems tool used within the framework of GMCR to determine how a DM may act under conflict given a desire to act in ways other than just self-improvement with no concern for other DMs. Understanding how conflict outcomes change due to the attitudes DMs hold for each other provides powerful strategic insights. Using soft computing methods, such as fuzzy numbers, attitudes of varying strength will be analysed.

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