DECISION SUPPORT SYSTEM FOR CONFLICT RESOLUTION IN CONSTRUCTION

Moustafa Kassab[1], Keith Hipel[2], and Tarek Hegazy[3]

ABSTRACT

Conflicts and disputes occur regularly throughout the entire construction process due to the complexity of operations and their conflicting resource requirements. At times, unresolved conflicts may slow or halt the entire project. In the past, many traditional methods have been used to resolve disputes, including starting with a simple resolution approach and ending with legal arbitration, which consumes time and money. However, in complex conflicts where multiple parties are involved, resolving conflict becomes a complex task and decision support tools are needed. This paper presents a new methodology to facilitate the negotiation that takes place among multiple parties in construction conflicts. Two fundamental theories are used in this methodology: 1) Game theory, which is the study of decision makers and their level of satisfaction in various actions/ counteractions; and 2) the Graph model for conflict resolution, which aims at analyzing the interactions among the decision makers, and reducing their differences to produce the most acceptable settlement.

Based on these two fundamental theories, this paper presents a collaborative negotiation methodology and a computer Decision Support System (DSS) named GMCR II, which facilitates the negotiation of multiple-party conflicts in large construction projects. The DSS allows all parties to express their options and interests to create various courses of actions. The DSS then helps in performing an in-depth analysis to ascertain the possible compromise resolutions or equilibria. Details on the DSS are provided in this paper and a case study of a construction conflict is used to demonstrate its application and potential benefits. Based on the case study results, the effectiveness of the proposed DSS system in conflict resolution is confirmed. This DSS is useful for both researchers and practitioners to better deal with the dispute prone-nature of the construction industry.

KEY WORDS

Construction management; Conflict resolution; Decision support system; Decision Analysis; Graph Model

1. Ph.D. Candidate, Systems Design Engrg., Univ. of Waterloo, Waterloo, Ontario, N2L 3G1 Canada, E-mail: mkassab@engmail.uwaterloo.ca
2. Prof., Systems Design Engrg., Univ. of Waterloo, Waterloo, Ontario, N2L 3G1, Canada E-mail: kwhipel@uwaterloo.ca
3. Prof., Civil Engrg., Univ. of Waterloo, Waterloo, Ontario, N2L 3G1, Canada, E-mail: tarek@uwaterloo.ca

INTRODUCTION

Resolving construction disputes through negotiation is necessary in today's constantly shifting business environment, where multiple parties have conflicting interests. Although construction has moved towards partnering arrangements in recent years, the number of construction claims continues to rise. In the past few years, for example, the number of claims submitted to the American Arbitration Association (AAA) reached almost 25% of the 1.7 millions claims over the past 74 years (AAA 2000). Considering the large damages that result from construction conflicts due to delays, cost overruns, and decreasing productivity, the construction industry needs to develop and employ new decision support technologies for resolving construction conflicts.

With the demand on negotiation and decision making skills continually increasing, particularly for engineers and project managers, many researchers have studied the reasons for construction claims and disputes. A survey by Semple et al. (1994) reported that the most common causes of claims are scope changes, weather, and restricted site access.

The main types of formal dispute resolution often employed in the construction industry are shown in Figure 1 (Kassab et al. 2006). The top six procedures are preferred over the litigation process since they are considered fast, friendly, and private. Litigation, on the other hand, represents the highest level of escalation, and is costly and time consuming (Panagiotis and Howell 2001). To support the decision process, various analytical tools have been used in the literature (Thiessen and Loucks 1992). For multiple-objective decision making, common tools include the Analytical Hierarchy Process (Saaty 1980) and the Multi-Attribute Utility Theory (Keeney and Raiffa 1976).

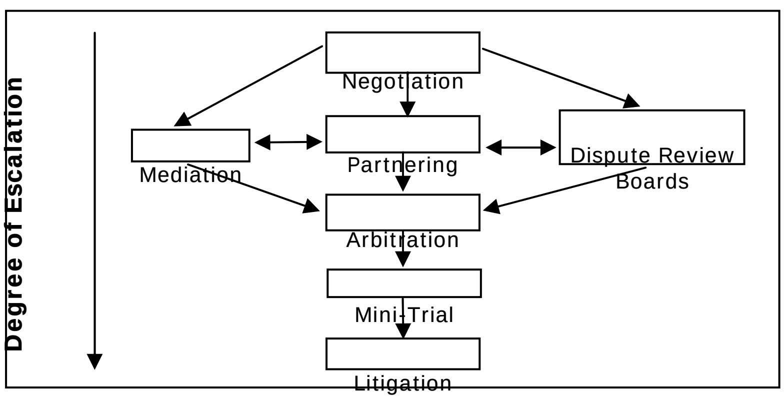


Figure 1: Dispute Resolution in Construction

Decision analysis tools are beneficial in evaluating and comparing alternative decisions made by a single party according to multiple criteria, and then ranking the alternatives from most to least preferred. Multiple-party conflicts, however, are more complex, and involve a series of actions and counter actions by participants and not just one final decision. For this type of problem, game theory methods are the most applicable. They furnish practical tools to analyze conflicts and provide an alternative methodology for resolving conflicts in many domains such as economics, engineering, and politics (Fang et al. 1993).

The objective of this paper is to introduce the graph model for conflict resolution (Fang et al. 1993) as an effective tool for investigating and resolving construction conflicts. A decision support tool called GMCR II is then introduced and applied to a dispute between the owner and the general contractor of a construction project. The analytical results closely predict the decisions that actually took place during the negotiation process and provide valuable insights about the strategic characteristics of the dispute.

CONFLICT RESOLUTION USING THE GRAPH MODEL

The graph model for conflict resolution uses mathematical logic and set theory to describe conflict situations in a graphical form (Hipel et al. 2002). Fang et al. (1993) provide background material on the graph model for conflict resolution. The basis of conflict analysis and resolution can be found in the book by Fraser and Hipel (1984).

ANALYSIS OF A TYPICAL CONFLICT SITUATION

Within the graph model paradigm, any conflict involves decision makers (DMs), their options, and their preferences. For simplicity, the graph model for conflict resolution is explained using the well-known "Prisoner's Dilemma" dispute (Axelrod 1984). This simple problem has been extensively studied to gain insights into human behavior in conflict situations (Fraser and Hipel 1984). This conflict also closely matches the behavior of decision makers in construction conflicts.

In his conflict, two individuals suspected of being partners in a crime are arrested and placed in separate cells so that they cannot communicate with one another. The district attorney does not have sufficient evidence to convict them for the crime. Consequently, to obtain a confession, the attorney presents each suspect with the following offers:

1. If one of them cooperates (C) with his partner (i.e., not confess) and the other does not cooperate (D) (i.e., confess), the one who cooperates receives a stiff 10-year sentence while the other one can go free for proving that they committed the crime.
2. If both prisoners do not cooperate with each other (i.e., both confess), both receive reduced sentences of 5 years.
3. If both cooperate by keeping silent, each receives a lesser charge of carrying a concealed weapon, leading to one year incarceration in prison.

In this conflict, each of the two DMs has two strategies, and as such, a total of four scenarios or decision states exist. A normal form representation of these four decision states (CC, CD, DC, DD) is shown on the left hand side of Figure 2. Notice in this matrix that DM 1, controls the row strategies while DM 2 controls the column strategies. When each DM selects a strategy, an outcome or state is formed, which is represented by a double letters inside each cell in that matrix, where the letter on the left and right hand reflects the strategies of DM 1 and DM 2, respectively. For example, the state CD or state number 2 represents the case in which DM 1 cooperates and DM 2 does not cooperate.

To represent this conflict using the graph model, the choices available to each DM are drawn using nodes and arcs as shown in the middle of Figure 2. For DM 1, his ability to change his decision from state 1 (CC) to state 3 (DC) or vice versa is shown by the arcs connecting nodes 1 and 3 (nodes represent decision states). Similarly, the ability of DM 1 to move between decision states 2 and 4 is shown by the arcs connecting nodes 2 and 4. Analogously, the second DM's choices are drawn as shown in the figure.

Below the graph in Figure 2 is the relative preference of each state for the corresponding DM where a higher number means more preferred. Hence, notice in Figure 2 that the most preferred state for DM 1 is state 3 or DC which is assigned a relative preference number of 4. At state 3 or DC, DM 1 is not cooperating (D) while DM 2 is cooperating (C) and thereby not confessing. For DM 2, the most preferred state is state 2 or CD while the least preferred state is state 3 or DC. By cooperating with one another, state 1 or CC can be jointly achieved and each DM does reasonably well. If the DMs do not cooperate, each DM attempts do as well as possible on his or her own and, hence, state 4 or DD is reached in which the DMs do not fare as well as at state CC.

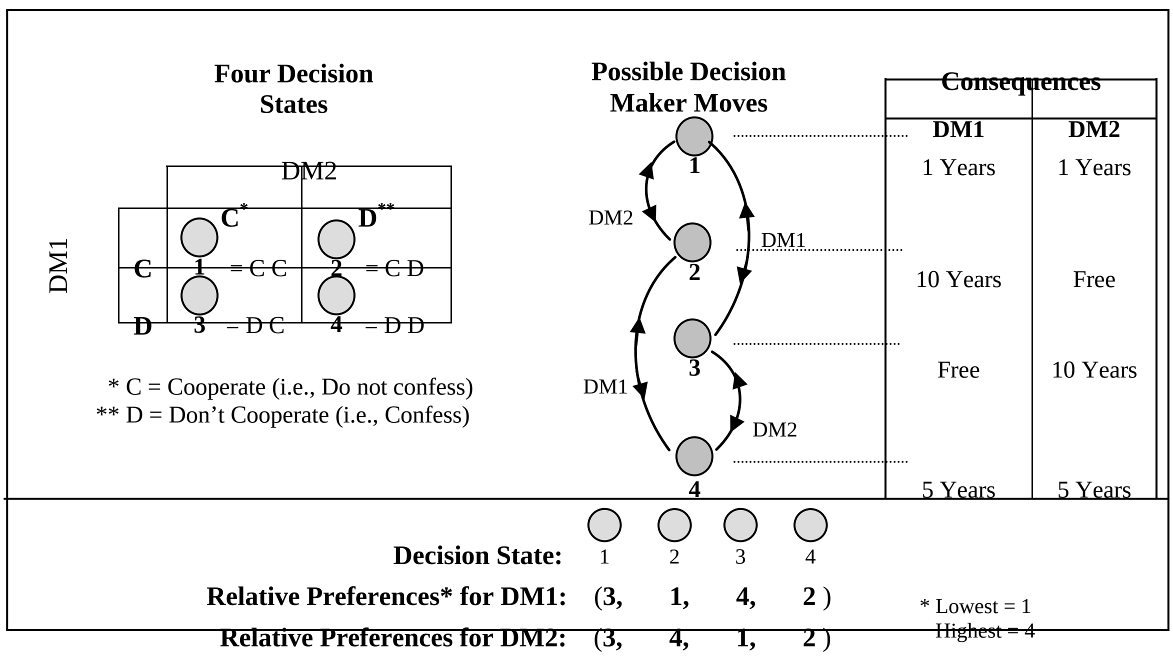


Figure 2: Graph Presentation of Prisoner's Dilemma

Because of the forgoing reasons, Prisoner's Dilemma constitutes a generic conflict for explaining how cooperation can or cannot be brought about in a dispute. For the construction industry, this dispute has widespread implications in dealings between a Contractor and an Owner. In reality, real-world conflict is more complicated than Prisoner's Dilemma as illustrated by the conflict examined later in this article.

Once the model is graphically represented, the conflict analysis continues by analyzing, for each DM, the stability of the decision states with respect to the solution concepts in Table 1, which represent different types of strategic thinking by DMs in conflict situations. The different solution concepts imply different levels of foresight (ability of a DM to consider possible moves that can take place in the future). A DM with high foresight thinks further ahead. In Table 1, the level of the foresight increases from low at the top (Nash: R) to highest at SMR and moderate forsight at GMR and SEQ. Some solution concepts, such as Nash (R) and sequential stability (SEQ), never allow disimprovements. Others, such as general metarationality (GMR) and symmetric metrationality (SMR) permit strategic disimprovements by opponents only. Different solution concepts also imply different levels of preference knowledge. Under R, GMR and SMR, for example, a DM needs only to know its own preferences. On the other hand, under the solution concept SEQ, a DM must know the preference information for all DMs. Finally, the solution concepts in Table 1 are commonly used and easier to implement.

Table 1: Main Stability Concepts

Stability Concept	Descriptions
Nash Stability (R)	Moving to a different state brings no benefit to the DM.
General Metarationality (GMR)	Moving to a more preferred state may trigger opponent counteraction with less benefit to the focal DM.
Symmetric Metarationality (SMR)	Moving to a more preferred state may trigger opponent counteraction to harm the DM even if the counteraction is self-harmful to the opponent. The focal DM's has the chance to counter-respond.
Sequential Stability (SEQ)	Moving to a more preferred state may trigger opponent counteraction to improve the opponent's benefits where self harmful counteractions are not considered.

In a stability analysis, if a certain decision state is found to be stable, for all of the DMs, with respect to one solution concept (e.g., Nash), then this decision state is in "equilibrium" for that concept (e.g., Nash Equilibrium). The final solution to the conflict may be the decision state that achieves equilibrium for most of the solution concepts. The mathematical formulations for the solution concepts in Table 1 are provided by Kassab et al. (2006).

SOLUTION STABILITY

Using the graph model, the game at hand is represented as shown in Figure 2. DM 1 can change his / her decision, and thereby, move the conflict between state 1 (CC) and state 3 (DC), or between state 2 (CD) and state 4 (DD). DM 2, on the other hand, can exercise his strategy selection to move the game between states 1 (CC) and 2 (CD), or between state 3 (DC) and state 4 (DD). Given these possible moves, the manual calculations of the different stability concepts are as follows:

1. Nash stability: A state is Nash stable for DM i, iff (if and only if) he/ she cannot unilaterally move to a more preferred state (Nash 1950, 1951). For example, state 3 (DC) in Figure 2 is Nash stable for DM 1 because this DM cannot unilaterally improve from this position. On the other hand, state 1 (CC) is unstable for DM 1 because he can move to state 3, which is more preferred for DM 1. Checking all the states for Nash stability, with respect to both DM 1 and DM 2 reveals that decision state 4 is Nash equilibrium because neither DM has a unilateral improvement away from state 4.

2. General Metarationality: In general metarationality (GMR) (Howard 1971), a DM examines all counteractions by his opponent. An example is when DM 1 moves from state 1 to state 3 to improve his position (from a preference of 3 to 4). But, by examining the counteraction of DM 2, one can see that DM 2 can move from state 3 to state 4, which is less preferred by DM 1 than state 1. As such, state 1 is GMR stable for DM 1. Similarly, checking all the states shows that states 3 and 4 constitute GMR equilibria. Note that if a state is Nash stable for a given DM, by definition it is also GMR, SMR and SEQ.

3. Symmetric Metarationality (SMR): In symmetric metarationality (SMR) (Howard 1971), a DM checks not only the counteractions of his opponent, but also, his response to these counteractions. For example, when DM 1 moves from state 1 to state 3, the counteraction of DM 2 can be to move from state 3 to state 4. Notice that state 4 is less preferred to state 1 by DM 1. Hence, DM 1 may try to escape from this sanction by moving from state 4 to state 2. Comparing the initial state (state 1) and the final state (state 2), results in DM 1 gaining no improvement. It can be shown that state 1 is also SMR stable for DM 2 and hence is an SMR equilibrium, along with state 4. It should be noted that in an SMR stability analysis, the leading DM should consider that his opponent might harm himself for the purpose of forcing the leading DM to a worse position.

4. Sequential stability: Sequential stability (SEQ) (Fraser and Hipel 1984) is similar to GMR, but only considers the opponent's beneficial moves (i.e., intention to harm the other party even by harming himself is not used). Consider the stability of state 1 for DM 1 who has a unilateral improvement to state 3. Subsequently, DM 2 has a unilateral improvement from state 3 to state 4, which is less preferred to state 1 by DM 1. Hence, state 1 is SEQ stable for DM 1. Because state 1 is also SEQ stable for DM 2, it forms an SEQ equilibrium. Finally, since state 4 is Nash stable for both DMs it is also an SEQ equilibrium.

Based on this stability analysis, it can be seen that only states 1 and 4 are possible equilibria or compromise resolutions. To achieve state 1 or CC, the cooperative equilibrium, both DMs must cooperate with one another to jointly cause the conflict to move from state 4 or DD to state 1 or CC which is more preferred by each of them.

GMCR II Decision Support System

The decision support system GMCR II (Hipel et al. 1997, 2002; Fang et al. 2003a, b) implements the graph model for conflict resolution within a Microsoft Windows environment, and does not require a conflict specialist or unusual hardware or software support. The structure of GMCR II is illustrated in Figure 3 and consists of a modeling subsystem, an analysis engine, and an output data subsystem.

Friendly prompts invite the user to input information such as the DMs and options, feasible states, allowable state transitions and preferences via the user interface to the modeling subsystem. Subsequently, GMCR II processes the input data and automatically produces a calibrated graph model to be used in the analysis of the conflict. The analysis engine determines the stability of each state for every DM to determine stable states and equilibria for all the solution concepts listed in Table 1. Finally, stored stability results can be easily retrieved using the output data subsystem, which controls every aspect of the display. The use of GMCR II with a construction conflict is illustrated next.

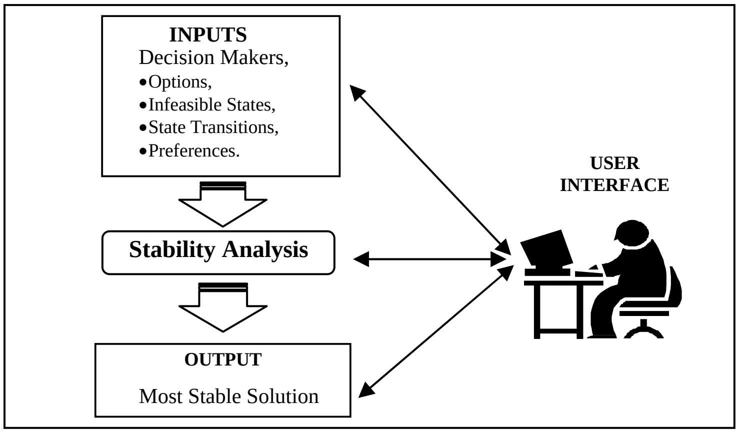


Figure 3**:** The Structure of GMCR II

CONSTRUCTION CASE STUDY

To demonstrate the value of the graph model for conflict resolution in the construction industry, an actual dispute is considered. The conflict arose in a building project in Ontario, Canada, between an Owner and a mid-sized Contractor, where names have been omitted for confidentiality. The total value of the project was $6 million, and the Contractor was awarded the job by being the lowest bidder. The Contractor started mobilizing resources and construction immediately after signing the contract. Later, when the job was almost 12% complete, a memo from the consulting office was sent to the Contractor questioning the delay in the submission of a shop drawing for a certain item. At that time, the Contractor discovered that he omitted a $450,000 item in his bid (almost 7.5% of the total contract value). Because of the tight market and high competition, the Contractor did not include any profit margin. The Contractor realized that his company would go bankrupt unless the Owner agreed to include the missing item. His main arguments were that the bid documents were not clear, bidding time was short, and many addenda were issued during bidding. While he officially rejected the Contractor’s request, the Owner’s need for a speedy completion of construction put some constraints on his negotiation options. The owner did not prefer to extend the negotiation time, take legal action, or assign a new contractor. The Contractor, on the other hand, threatened to declare bankruptcy but preferred a way to complete the work.

The construction conflict was formally modeled using GMCR II. The program accepts as input any number of DMs, each having any number of options. A given DM may represent an individual person, a group of people, or an organization. Two DMs were specified for the current construction conflict: the Owner and the Contractor. The Owner’s basic options were as follows: full payment of additional cost to the contractor (Full), partial payment (Partial), acquire a new contractor (New), or take legal action (Legal). The Contractor, on the other hand, had the following options: continue the job without extra payment (Continue); accept partial payment from the Owner (Accept); or declare bankruptcy (Bankruptcy). Based on the DMs entered, Figure 4 shows the list of the feasible decision states generated by GMCR II.

Each decision state (or scenario) in Figure 4 is represented by a set of yes (Y) and/or no (N) values associated with each decision option. For example, state 7, represents the case at which the Owner will consider suing the Contractor (as denoted by "Y" opposite to the legal option) and the contractor will be forced to complete the job as per a court order (denoted by "Y" opposite to continuing the work). It should be noted that the Status Quo (State 1) is represented by a "NO" associated with each decision option.

A conflict having k options contains a total of 2^k mathematically possible states. In the present case study, there are a total of 7 options across the two DMs, which leads to a total of 2^7=128 possible scenarios or states. Given the large number of possible states and the complexity associated with choosing the strategically feasible states, GMCR II gives the user the ability to eliminate infeasible states. The DSS has various approaches to identify infeasible states. For example, selecting the "Mutually Exclusive Options" approach enables the user to specify the states that must be eliminated because they involve options that could not exist together. For example, it is unrealistic for the Contractor to declare bankruptcy as a response to the Owner's decision to offer the Contractor full payment. Following the elimination process, 114 out of the 128 decision states were removed, leaving only the 14 feasible states shown in Figure 4.

An important step in conflict analysis is to specify each DM's preferences among the feasible states. When employing GMCR II, for each DM, the user has to enter preference information that will guide the program in ranking the decision states. Based upon these inputs, GMCR II constructs a ranking of the states through either weighting or option prioritization. Based on these preferences, GMCR II ranked the states according to the Owner and Contractor's prioritized preference statements as indicated in Figure 4. Kassbb et al. (2006) provide a detailed explanation of the preferences for each DM.

Most preferred state

Least preferred state

DMs	Options	9	6	5	14	3	10	12	1	7	11	8	13	4
Owner	1. Full	N	N	N	N	N	N	N	N	N	N	N	N	N
	2. Partial	Y	N	N	N	Y	N	Y	N	N	N	N	N	N
	3. New	N	N	N	N	N	N	N	N	N	N	N	Y	Y
	4. Legal	N	N	Y	Y	N	Y	N	N	Y	N	N	N	N
Contractor	5. Continue	N	Y	N	N	N	N	N	N	Y	N	N	N	N
	6. Accept	Y	N	N	N	N	Y	N	N	N	N	Y	N	N
	7. Bankrupcy	N	N	N	Y	N	N	Y	N	N	Y	N	Y	N

Owner's State Ranking: 9, 6, 5, 14, 3, 10, 12, 1, 7, 11, 8, 13, then 4

Contractor's State Ranking: 14, 11, 13, 4, 1, 5, 10, 8, 9, 3, 12, 2, 6, then 7

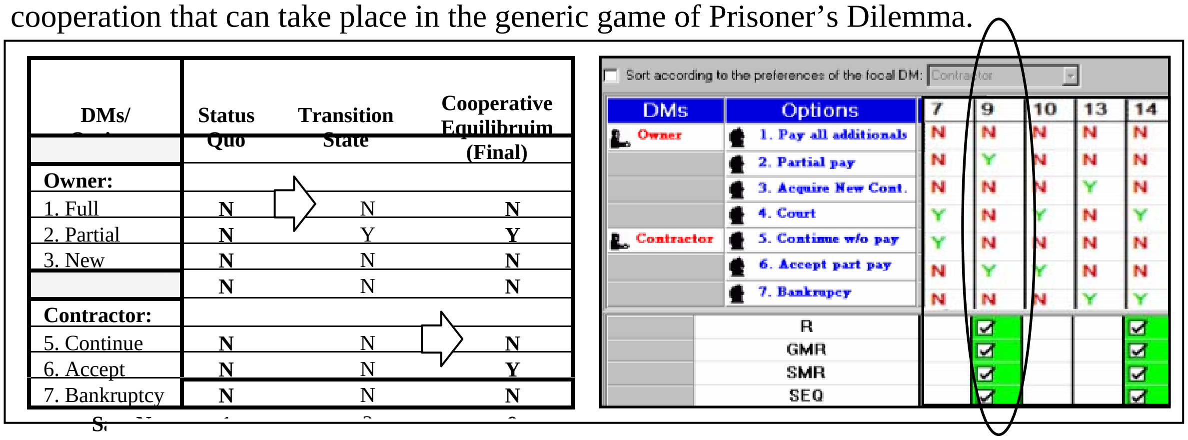
Figure 4: Decision Makers, Decision Options, and Feasible Decision States (Sorted)

Once the conflict model was developed, an exhaustive stability analysis was conducted. GMCR II calculates the stability of each feasible state for every DM with respect to all the solution concepts in Table 1. When a given state is stable for all DMs according to a given stability concept, it is deemed to be an equilibrium or compromise resolution since no DM has an incentive to move away from it (Hiple et al. 1997).

Based on the stability analysis, Figure 5 shows the states that are in equilibrium (equilibria). The two most stable states are states 9, and 14, since they are stable according to all the solution concepts. This result means that if the conflict were to arrive at one of these states, it would stay there since it would be in equilibrium. In state 9, the Owner will pay part of the requested expenses, and the Contractor agrees to complete the job. In state 14, on the other hand, the Owner will refuse to pay the Contractor any compensation, and will take legal action, which will trigger a bankruptcy decision by the Contactor.

It is noted that state 14 represents the case where the conflict has been resolved unwisely, based upon the job circumstances. State 9, on the other hand, shows that the wisest decision that the two DMs could reach with the minimum possible loss for both parties.

In reality, what happened in this conflict matches the GMCR II results. After several meetings between the representatives of both parties, and intense negotiations, the Contractor agreed to continue and complete the project in exchange for a cost compensation for the missing item, which matches state number 9. This state represents the best equilibrium state, since no DM has an incentive to move away from it. As shown in Fig. 5, state 9 was reached by the Owner moving from state 1 (status quo) to the less preferred transition state in order to save already-wasted time, since all other moves would further delay the project. Next, a wise response from the Contractor in showing his good well and saving his business reputation led him to accept cost recovery only. Notice that this type of cooperation reflects the kind of cooperation that can take place in the generic game of Prisoner's Dilemma.



DMs/	Status Quo	Transition State	Cooperative Equilibruim (Final)
Owner:			
1. Full	**N**	N	**N**
2. Partial	**N**	Y	**Y**
3. New	**N**	N	**N**
	N	N	**N**
Contractor:			
5. Continue	**N**	N	**N**
6. Accept	**N**	N	**Y**
7. Bankruptcy	**N**	N	**N**

DMs	Options	7	9	10	13	14
Owner	1. Pay all additionals	N	N	N	N	N
	2. Partial pay	N	Y	N	N	N
	3. Acquire New Cont.	N	N	N	Y	N
	4. Court	Y	N	Y	N	Y
Contractor	5. Continue w/o pay	Y	N	N	N	N
	6. Accept part pay	N	Y	Y	N	N
	7. Bankrupcy	N	N	N	Y	Y
	R		☑			☑
	GMR		☑			☑
	SMR		☑			☑
	SEQ		☑			☑

Figure 5: The Final Equilibrium Results and Evolution process

It is noted that the resolution was only possible because the Owner was under a critical time constraint in this project. The Contractor was fully aware of this fact. As a result of this conflict, the Owner expressed sensitivity in future dealings with this Contractor, and a memo was issued by the Owner's head office to modify the bidding procedure to avoid automatic awarding construction work to the lowest bidder or to unreasonable bids.

CONCLUSIONS

Construction conflicts are often unavoidable. However, minimizing their impact brings many advantages, such as, reducing contractual problems, training construction personnel on resolving problems, and establishing alternative dispute resolution mechanisms. In this paper, the graph model for conflict resolution and the associated decision support system GMCR II have been demonstrated to be flexible and efficient means for analytically investigating strategic disputes. GMCR II provides significant insights that can assist decision makers in taking steps towards more favorable outcomes, as demonstrated in the construction case study. The results confirmed that any tough position will lead eventually to the worst case scenario, in addition to the extra cost and time wasted in by the legal process. Finally, in construction projects, an effective and cooperative project team (Owner, Contractor, and Consultant) can minimize the effect of large complex problems. Organizations' ability to solve problems and agree on responsibility depends on the parties' intentions, behavior, relationships, and decision processes. The key factor is to try to encourage all parties to cooperate rather than compete on projects. In the most basic form, this kind of collaboration is embedded in the game of Prisoner's Dilemma.

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