COMPARISON OF THE ANALYTIC NETWORK PROCESS AND THE GRAPH MODEL FOR CONFLICT RESOLUTION

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Abstract

A comparison of two decision analysis tools for the analysis of strategic conflicts, the Analytic Network Process (ANP) and the graph model for conflict resolution, is carried out by applying them to the China-US TV dumping conflict. Firstly, the graph model is introduced along with practical procedures for modeling and analyzing conflicts using the decision support software, GMCR II. Next, ANP is explained, emphasizing structural features and procedures for synthesizing priorities. Then a framework for employing ANP to analyze strategic conflicts is designed and used to compare ANP to the graph model. The case study of the China-US TV dumping conflict provides a basis for the graph model and ANP to be compared; different features of the approaches are highlighted. The study shows that because of different theoretical backgrounds, ANP and the graph model for conflict analysis both provide useful information which can be combined to furnish a better understanding of a strategic conflict.

Keywords: Strategic conflict, graph model for conflict resolution, Analytic Network Process, decision support system, China-US TV dumping conflict

1. Introduction

A strategic conflict is a situation in which two or more decision-makers are to make a decision that affects issues they have different preferences about (Fang et al. 1993). Conflicts are one of the most characteristic attributes of human societies. Various forms of strategic conflict exist all around us, in areas such as environmental management, international relations, economic competition, and relationships among individuals.

Conflicts are studied in a wide range of disciplines including social science, game theory, and information and decision sciences, in which researchers conceptualize and analyze conflicts from different perspectives. Social scientists focus mainly on the qualitative study of conflicts, describing how to improve relationships among individuals, groups, organizations, and nations (Daniel 2000). Other fields, including operations research, game theory, economics, information and decision sciences concentrate on qantitative studies, explaining conflicts using mathematical models. Myerson (1991), for example, provides a thorough examination of the models, solution concepts, and methodological principles of game theory approaches for conflict analysis; Pawlak (1998, 2005) uses rough set theory for the same purpose.

In this paper, we focus on a comparison of two quantitative approaches to conflict analysis: the graph model for conflict resolution (Fang et al. 1993) and the Analytic Network Process (ANP) (Saaty, 2001). ANP and the graph model are based on different principles: ANP is a decision-theory-based technique, while the graph model is a game-theory-related technique. The objective of this paper is to compare ANP and the graph model by applying them to the same realworld conflict. Our study highlights distinctive features of both methods and shows that both methods provide different information for better understanding the conflict. The remainder of the paper is organized as follows. Section 2 introduces the graph model. Section 3 explains ANP within a framework designed for conflict analysis. Section 4 presents a case study in which ANP and the graph model are applied to the China-US TV dumping conflict. Finally, some conclusions are put forward in Section 5.

2. The Graph Model for Conflict Resolution

2.1 History

Howard (1971) developed metagame analysis with option form for structuring and modelling a conflict problem; Fraser and Hipel (1984) extended metagame analysis to conflict analysis; Fang et al. (1993) proposed the graph model for conflict resolution, which is an expansion and reformulation of conflict analysis. Meanwhile, Saaty (1980) developed the analytic hierarchy process (AHP) process for decision analysis, Alexander (1983), and Saaty and Alexander (1989) employed AHP for conflict analysis, and Saaty (2001) created the analytic network process (ANP) as a generalization of AHP. Vargas (1985) reviewed the conflict analysis approach of Fraser and Hipel (1984) and compared it with the AHP method, summarizing the different features of the two methods.

2.2 Modeling Conflicts Using the Graph Model

The graph model is founded upon a rigorous mathematical framework, utilizing concepts from graph theory, set theory and logic — the mathematics of relationships. GMCR II is the latest decision support system that adapts the graph model for conflict resolution to the modeling and analysis of realworld conflicts (Fang et al., 2003a,b). There have been many practical applications of the graph model for conflict analysis (Hipel et al., 2001, Obeidi et al., 2002, Noakes et al., 2003).

The graph model approach is quite different from classical game (von Neumann and Morgenstern, 1953), although there are some connections; Fang et al. (1993) explain the relationship between the graph model and extensive-form games. The graph model focuses on analyzing a strategic conflict in terms of its components: decision makers (DMs), states, transitions, options, and preferences. It searches for possible resolutions based on certain stability definitions, which mathematically describe how DMs interact with one another in terms of moves and countermoves.

Figure 1 shows the steps involved in applying the graph model. A graph model study consists of two main stages: modeling and analysis. During the modeling stage, one must first identify the decision makers (DMs) involved in the conflict, as well as the options controlled by each DM. Ascertaining the relative preferences for each DM over all feasible

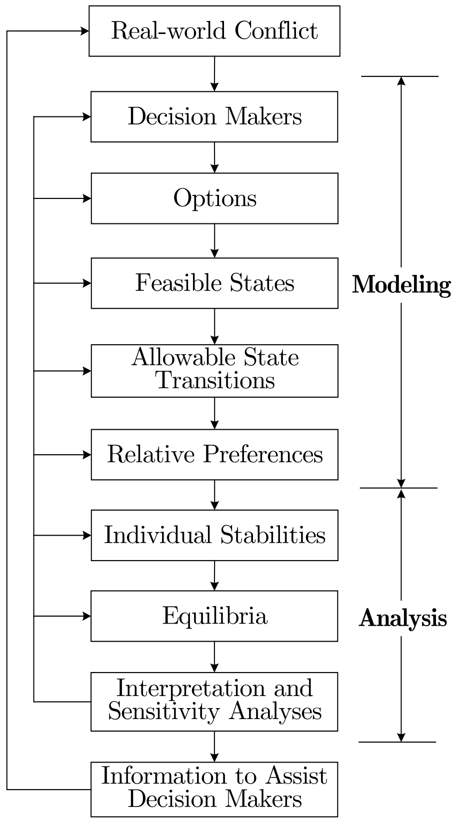

Figure 1 The analysis procedure of the graph model, adapted from Fang et al. (1993)

states is another important component of the modeling process. During the stability analysis, each DM's willingness to accept various possible states as resolutions is assessed in detail; when a state is stable for every DM it represents a possible resolution or equilibrium. In a sensitivity analysis, the robustness of the stability results is examined with respect to changes in model parameters, such as DMs' preferences. The stability and sensitivity analyses can be interpreted, by analysts, actual DMs, or interested parties, in order to gain guidance for enhanced decision making. The graph model notation is introduced next.

Let $N = \{1, 2, ..., r\}$ denote the set of DMs and $S = \{s_1, s_2, ..., s_t\}$ the set of states, or possible scenarios of the conflict. A collection of finite directed graphs, $\{D_i = (S, A_i), i \in N\}$ is a fundamental part of a graph model, where the vertices of each graph are the possible states of the conflict, S . Note that each DM's graph has the same state set. Each DM i , $i \in N$ has a ranking of the set of states, S , which may include ties. DM i 's preference ranking is denoted using $\succ_i$ (strict preference), $\succeq_i$ (week preference), and $\sim_i$ (indifference).

States are stable for a given DM, in the sense that he or she will not be motivated to unilaterally depart from them, are determined by solution concepts that, although defined mathematically describe a rich range of potential human behaviour under conflict. When a given state is stable for all DMs with respect to an appropriate solution concept, it is called an equilibrium or potential resolution. Table 1 outlines the solution concepts available for use within the software GMCR II, described below. Formal definitions, explanations, examples, and original references are collected by Fang et al. (1993, Chapter 3).

Table 1 Solution concepts and human behaviour, adapted from Fang et al. (1993)

Solution Concepts	*Stability Descriptions*
Nash stability (*R*)	Focal DM cannot unilaterally move to a more preferred state.
General metarationality (*GMR*)	All of the focal DM's unilateral improvements are sanctioned by subsequent unilateral moves by others.
Symmetric metarationality (*SMR*)	All focal DM's unilateral improvements are still sanctioned even after possible responses by the focal DM.
Sequential stability (*SEQ*)	All of the focal DM's unilateral improvements are sanctioned by subsequent unilateral improvements by others.
Limited-move stability (L_h)	All DMs are assumed to act optimally and a maximum number of state transitions (h) is specified.
Non-myopic (*NM*)	Limiting case of limited move stability as the maximum number of state transitions increases to infinity.

2.3 Decision Support System GMCR II

The decision support system GMCR II implements the Graph Model for Conflict Resolution within a Windows environment (Fang et al. 2003a,b). The structure of GMCR II is shown in Figure 2.

A user inputs the DMs, their options, patterns of infeasible states, allowable state transitions, and preference information. Then GMCR II generates the states and transitions, and carried out a stability analysis. Based on the information generated at the modelling stage, the analysis engine performs a thorough stability analysis on the conflict model. The analysis engine determines the stability of every state, for each DM, under the range of solution concepts listed in Table 1. The output interpretation subsystem presents the stability results in a user-friendly manner. Information about individual stability, equilibria, and coalition stability is easily identified and interpreted.

3. Analytic Network Process (ANP)

3.1 Structural Features

The ANP generalizes a widely used multiple criteria decision analysis tool, AHP, by replacing

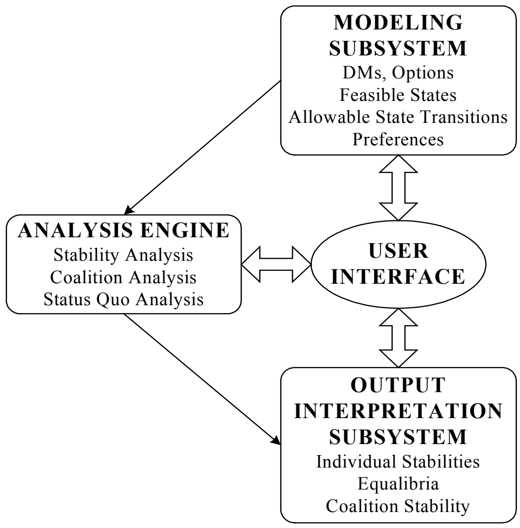

Figure 2 The analysis components in GMCR II, adapted from Fang et al. (1993)

hierarchies with networks. AHP is based on the following principles:

(1) The overall objective of the decision problem is decomposed into sub-objective levels in a hierarchy. Elements of approximately equal importance are arranged at the same level. For example, in a decision problem the overall objective is represented by a few criteria at the criteria level. Then for each criterion, sub-criteria that represent it are located at the sub-criteria level.

(2) Once a hierarchical structure is established, pairwise comparisons ratio scale of the elements at each level of the hierarchy must be carried out. Local priorities can then be generated by an eigenvalue technique.

(3) Based on linear additive aggregation, the global priority of each element to the overall objective is determined.

ANP allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback can capture complex interplay, and is especially appropriate when risk and uncertainty are involved. ANP has been applied to a wide variety of decision situations, including marketing, medical, political, societal forecastings, and many others. Its accuracy of prediction has been impressive in applications to economic trends, sports and other events (Saaty, 2001).

ANP permits interrelationships among different decision levels to be taken into consideration in a general form. Figure 3 shows the structural differences between AHP and ANP. In an ANP network, nodes represent components of the system that are composed of homogeneous elements, and

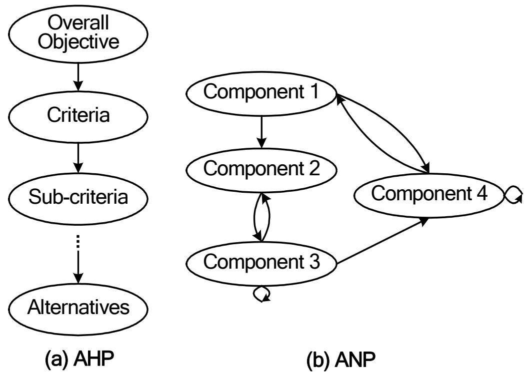

Figure 3 Structural differences between AHP and ANP

arcs represent the interactions between them. The directions of the arcs represent dependence, whereas loops signify dependence of the elements within a component. Obviously, the hierarchical structure of AHP is a special case of the network structure of ANP.The two main stages involved in applying ANP are:

(1) Construction of the network: to structure the problem, all of interactions among the elements should be considered. Let $C = \{C_1, C_2, ..., C_m\}$ denote the component set in an ANP system. Assume that component $C_p = \{e_p^1, e_p^2, ..., e_p^j, ..., e_p^{n_p}\}$ and note that C_p has n_p elements. Three different impact relationships can be identified: (a) when the elements in a component C_p depend on another component C_q, we represent this relationship with an arrow, $C_q \to C_p$; (b) when the elements of two components mutually impact each other, we represent it as $C_q \rightleftarrows C_p$; (c) when the elements in component C_h have inner impacts, we represent it as $C_h^{\circlearrowleft}$;

(2) Calculation of the priorities of elements: first pairwise comparisons are carried out for each kind of impact relationship defined above. Local priorities are next generated using the

eigenvalue method. Then using this local priority information, a supermatrix is set up to describe interactions among all elements. Next, a weighted supermatrix is designed so that its powers converge to a limit and thereby a global priority vector is obtained, that takes account of the cumulative influence of each element on every other element in the network.

The procedure for synthesizing priorities is explained next.

3.2 Synthesizing Priorities in ANP

Suppose an ANP network has components $C=\{C_1,C_2,...,C_p,...,C_m\}$. For components $C_p=\{e_p^1,e_p^2,...,e_p^j,...,e_p^{n_p}\}$ and $C_q=\{e_q^1,e_q^2,...,e_q^j,...,e_q^{n_q}\}$, let $W_{pq}(n_p\times n_q)$ denote component C_P's priority (impact) matrix on C_q and let $W_{pq}^j = (w_{pq}^{1j},w_{pq}^{2j},...,w_{pq}^{ij},...,w_{pq}^{n_pj})^T(n_p\times 1)$ denote the priority vector of C_p on element e_q^j in C_q, where $w_{pq}^{ij}\in\mathbb{R}$ and $w_{pq}^{ij}\geq 0$, $\sum_{i=1}^{n_p} w_{pq}^{ij}=1$ and T denotes the transpose of a vector or matrix. The priority vectors are derived from pair-wise comparisons; an element with no influence on another element has impact priority zero. When a component has no impact on another, the priority matrix is the *zero matrix*. Figure 4 shows the priority matrix W_{pq}.

Similarly, for component C_p, the inner priority matrix $W_{pp}(n_p\times n_p)$ can be constructed. The priority of an element on itself is set of zero. Figure 5 shows the priority matrix W_{pp}.

$$\boldsymbol{W}_{pq} = \begin{array}{c} \\ e_p^1 \\ e_p^2 \\ \vdots \\ e_p^{n_p} \end{array} \begin{array}{c} \begin{array}{cccc} e_q^1 & e_q^2 & \cdots & e_q^{n_q} \end{array} \\ \left[\begin{array}{c|c|c|c} w_{pq}^{11} & w_{pq}^{12} & \cdots & w_{pq}^{1n_q} \\ \hline w_{pq}^{21} & w_{pq}^{22} & \cdots & w_{pq}^{2n_q} \\ \hline \vdots & \vdots & \vdots & \vdots \\ \hline w_{pq}^{n_p1} & w_{pq}^{n_p2} & \cdots & w_{pq}^{n_pn_q} \end{array}\right] \end{array}$$

Figure 4 The priority matrix W_{pq}

$$\boldsymbol{W}_{pp} = \begin{array}{c} \\ e_p^1 \\ e_p^2 \\ \vdots \\ e_p^{n_p} \end{array} \begin{array}{c} \begin{array}{cccc} e_p^1 & e_p^2 & \cdots & e_p^{n_p} \end{array} \\ \left[\begin{array}{c|c|c|c} 0 & w_{pp}^{12} & \cdots & w_{pp}^{1n_p} \\ \hline w_{pp}^{21} & 0 & \cdots & w_{pp}^{2n_p} \\ \hline \vdots & \vdots & 0 & \vdots \\ \hline w_{pp}^{n_p1} & w_{pp}^{n_p2} & \cdots & 0 \end{array}\right] \end{array}$$

Figure 5 The priority matrix W_{pp}

The number of elements in an ANP network is $n=\sum_{p=1}^{m} n_p$. All priority matrices in the network can be combined into a "supermatrix", in which each entry indicates the influence of the row element on the column element. We denote this supermatrix $W(n\times n)$ as shown in Figure 6. The vector of priority matrices on C_q, V_q, is defined as $V_q=(W_{1q},W_{2q},...,W_{pq},...,W_{mq})^T$ representing all components' influences on C_q. Therefore, $W=(V_1,V_2,...,V_m)$.

To make the powers of W converge to the limit, for $q=1,2,...,m$, a weight vector $\alpha_q=(\alpha_q^1,\alpha_q^2,...,\alpha_q^p,...,\alpha_q^m)^T$ is assigned to $V_q=(W_{1q},W_{2q},...,W_{pq},...,W_{mq})^T$ to represent the ratio of impacts from different components on

C_q , where $\alpha_q^p \in \mathbb{R}$ and $\alpha_q^p \geq 0$, and $\sum_{p=1}^{m} \alpha_q^p = 1$. When W_{pq} is a zero matrix, the weight α_q^p equals zero. The weighted priority matrix vector for C_q , $\overline{V_q}$ is defined as $\overline{V_q} = (\alpha_q^1 \cdot W_{1q}, \alpha_q^2 \cdot W_{2q}, ..., \alpha_q^p \cdot W_{pq}, ..., \alpha_q^m \cdot W_{mq})^T$, where $\cdot$ is the scalar product. *Weighted supermatrix*, $\overline{W}$ is defined as $\overline{W} = (\overline{V_1}, \overline{V_2}, ..., \overline{V_m})$. The limiting supermatrix is denoted as $\overline{W}_\infty = \lim_{k\to\infty} (\overline{W})^k$. Since $\overline{W}$ is irreducible and primitive, it has limiting values (Saaty 2001). Then, $\overline{W}_\infty = (V_\infty^1, \ V_\infty^2, ..., V_\infty^i, ..., V_\infty^n)$, where $V_\infty^1 = V_\infty^2 = ... = V_\infty^i = ... = V_\infty^n = V_\infty = (v_1, v_2, ..., v_j, ..., v_n)^T$, is the global priority vector representing the overall priorities of each element considering all interactions in the network. Note that n is the number of elements, $v_j \in \mathbb{R}^+$ and $\sum_{i=1}^{n} v_j = 1$. The global priority vector, V_∞ , is intended to provide information to assist the DM in making decisions.

3.3 Analytic Network Process for Conflict Analysis

Recall that in a graph model, there is a set $N = \{1, 2, ..., r\}$ of DMs and a set of $S = \{s_1, s_2, ..., s_t\}$ of feasible states. To employ ANP in conflict analysis and to carry out a combination study of ANP and the graph model, a network is designed to represent a conflict problem as shown in Figure 7.

Two components constitute the network for a graph model: the decision makers (N) and the feasible states (S). There are three arcs in the system representing three interactions: (1) W_{SN} , the priority matrix of S on N , which represents the relative importance (state ranking) of feasible states for a given DM. (2) W_{NS} , the priority matrix of N on S , which estimates the possibilities that DMs are satisfied with given feasible states. (3) W_{NN} , which represents the inner impacts among DMs.

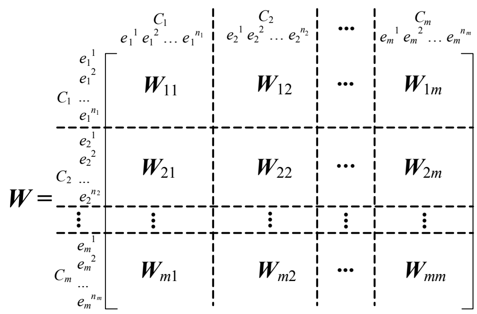

Figure 6 Supermatrix in ANP

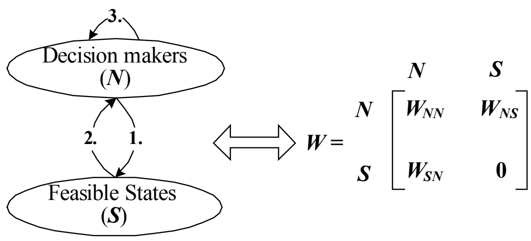

Figure 7 ANP structure for a graph model

The weighted supermatrix is thus

$$\overline{W} = \begin{bmatrix} \alpha_1 W_{NN} & W_{NS} \\ \alpha_2 W_{SN} & 0 \end{bmatrix}$$

where α_1 and α_2 represent the relative importance of W_{NN} and W_{SN} , and $\alpha_1 + \alpha_2 = 1$. The ratio α_1 / α_2 represents how strongly DMs influence themselves, as compared with their influence on the feasible states contained in the set S .

The limiting supermatrix is calculated using $\overline{W}_\infty = \lim_{k\to\infty} (\overline{W})^k$, and V_∞ is obtained from $\overline{W}_\infty$. Let $V_\infty = (V_N, V_S)^T$, where $V_N = (v_N^1, v_N^2, ..., v_N^i, ..., v_N^r)$ represents the global priority vector of DMs and $V_S = (v_S^1, v_S^2, ..., v_S^i, ..., v_S^t)$ represents the overall priority vector of feasible states. V_N provides information about the relative impact of DMs in the conflict: a greater value of v_N^i indicates that DM i has greater influence on other DMs. V_S provides information about the overall preferences for the feasible states; a greater value of v_S^i indicates that state s_i has higher preference among all DMs. Let $s_i^* = \{s_i \in S : \max v_S^i, i = 1, 2, ..., t\}$ stand for the most stable state, s_i^* which can be regarded as the equilibrium in a conflict considering all impact factors. By changing the ratio α_1/α_2, sensitivity analysis can be carried out to check the stability of s_i^*.

Figure 8 summarizes the procedure for combination studying of the graph model and ANP.

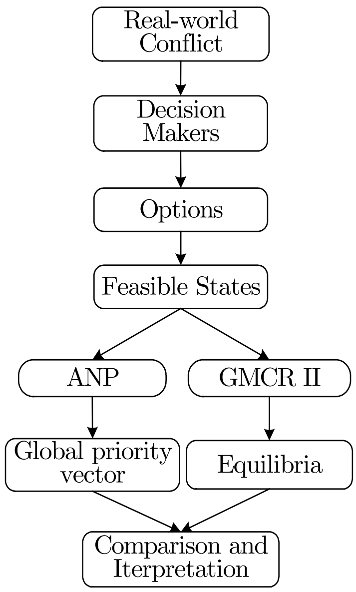

Figure 8 Combination study of GMCR II and ANP

4. Case study: the China-US TV Dumping Conflict

The comparison of the graph model and ANP is based on, a case study of the China-US TV dumping conflict. Some historical background is given first.

4.1 Background Information

Over the past ten years, China has become the world's largest producer of TV sets. Chinese color TV exports have increased dramatically since the year 2000. In its heyday, 2002, the number of exported color TV sets reached 18.82 million units, with a total value of US $2.14 billion. The US receives more Chinese TVs than any other countries. US retailers, such as Wal-Mart and SEARS, as well as dealers like APEX Digital, gain great benefits from Chinese TV sales and accelerated Chinese TV exports in US. American, Japanese, Korean, and European TV makers have lost American market share, and are gradually withdrawing from the US market.

On May 2, 2003, the US TV manufacturer, Five Rivers Electronic Innovations, and two labor unions, the International Brotherhood of Electrical Workers and the International Union of Electrical, Electronic, Furniture and Salaried Workers, formally accused TV manufacturers in China of unfair trade practices and argued for the imposition of duties of up to 84% on Chinese-produced TV sets. The accusation covered all Chinese TV manufacturers exporting products to the US. Most of China's major TV manufacturers were affected, including Changhong, Haier, Konka and TCL.

The US Department of Commerce (DOC) must decide whether to accept the case. If it were accepted, DOC would make an anti-dumping ruling. Chinese TV manufacturers, who were united and prepared to fight the charge, negotiated with DOC and US TV manufacturers about increasing prices or constraining the TV exports under a quota that would appease US TV manufacturers and smooth the dispute. Because Chinese TV sales in the US were very profitable, some retailers such as Wal-Mart strongly supported the Chinese TV manufacturers, and expected that China could win the dispute.

On June 16, 2003, DOC ruled, with three votes to zero that sales of Chinese color TV sets constituted substantial damage to the US color TV industry. Although it was under pressure from China, DOC decided to investigate four representative Chinese firms and differentiate anti-dumping duties among Chinese TV manufacturers (US Department of Commerce, 2004). On November 24, 2003, after the first round of investigations, DOC released its initial ruling that China was dumping its color TV sets into the US market and applied anti-dumping duties ranging from 27.94% to 78.45% to various Chinese TV manufacturers (Labor Research Association, 2003).

Fearing that the preliminary anti-dumping ruling would lead to a sharp decline, Chinese TV manufacturers filed suit against the initial ruling. The Chinese government also become involved, expressing deep concern over the dispute, and declaring that it would consider levying retaliatory duties on US products if DOC retained the initial import duty in its final conclusion (Chineses Embassy in US, 2004). DOC began a second round of field surveys in China from December 8 to 26, 2003. On April 13, 2004, DOC released its final ruling, confirming that Chinese manufacturers were dumping TVs in US market, but dropping the anti-dumping duties.

4.2 Modeling the Conflict as of April, 2004

The stage of the China-US TV dumping conflict between DOC's initial ruling (Novmber 24, 2003) and the scheduled time for its final ruling (April 13, 2004) is selected for study. The date of April 12, 2004 is chosen as the time of the analysis.

4.2.1 Select Decision Makers and Their Options

There are three DMs involved at this stage: the Chinese TV manufacturers (CNTVs), US Department of Commerce (DOC), and Chinese Government (CNG). The only option for CNTVs is *file* — file a suit against the initial anti-dumping ruling. The options for DOC are: *retain* — retain the import duty; *drop* — drop the import duty; and *cancel* — cancel the initial ruling. The options for CNG are: *support* — support CNTVs against DOC's initial ruling; and *levy* — levy retaliative duties on US products.

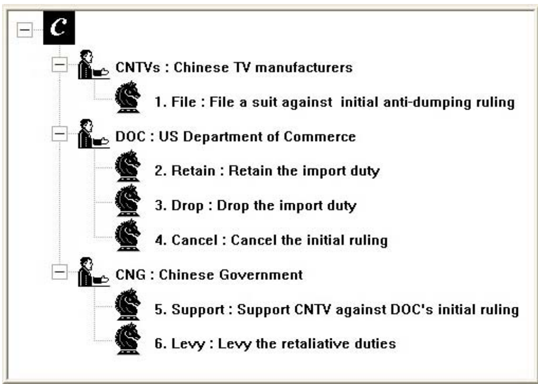

Figure 9 The DMs and their options

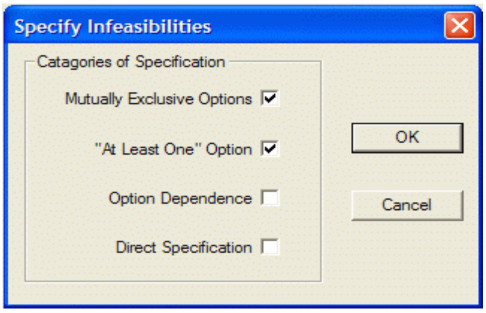

Figure 10 Removing infeasible states

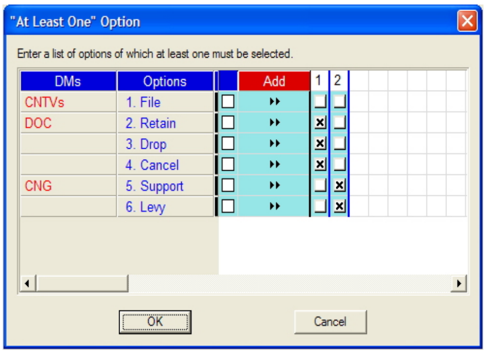

Figure 11 Mutually exclusive options

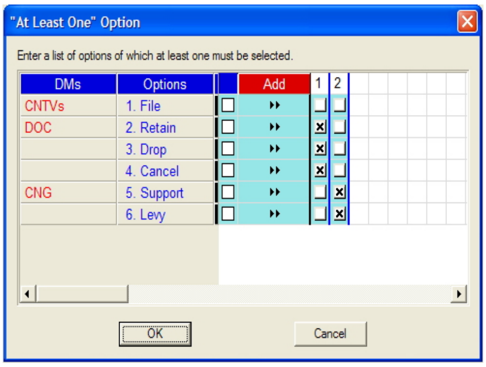

Figure 12 Removing infeasible states

4.2.2 Infeasible State Removal

GMCR II provides a range of techniques to remove infeasible states. In this conflict, *mutually exclusive options* and *at least one option* are chosen to remove the infeasible states, as shown in Figure 10.

DOC's three options are mutually exclusive, since DOC would only choose one of its options. The means to input this information into GMCR II is indicated by the Xs in the two columns on the right in Figure 11.

DOC's and CNG's options also subjected to the constraint of selecting at least one option. This means that DOC and CNG must choose one option; neither DM can do nothing. Figure 12 illustrates how this information is input into GMCR II using two columns of Xs.

4.2.3 Coalesce Indistinguishable States

When CNTVs reject their option of filing against the initial ruling, then no matter what the other DMs' strategies are, the conflict is over. Therefore, all option combinations satisfying this condition are indistinguishable, and should be treated as a single state. The coalescing indistinguishable specification is shown in Figure 13.

4.2.4 Feasible State Generation

After the infeasible states are removed and indistinguishable states are combined using GMCR II, the system generates all feasible states in the TV dumping conflict model, as shown in Figure 14.

4.3 GMCR II Approach to Conflict Analysis

4.3.1 State Ranking

GMCR II incorporates a flexible and convenient methodology to elicit a user's assessment of each DM's relative preferences: option weighting, in which weights are assigned to each option, and total weights of states used to determine an ordering; option prioritizing, based upon a set of

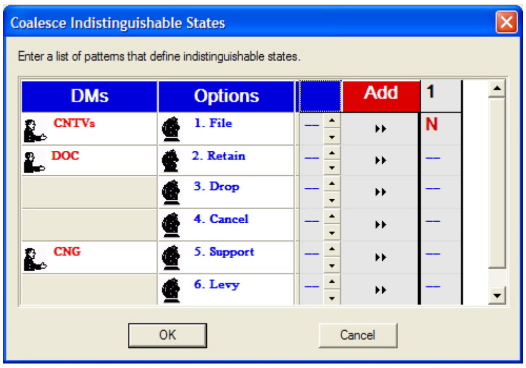

Figure 13 Indistinguishable state specification

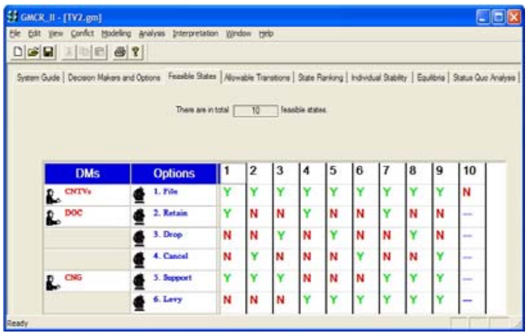

Figure 14 Feasible states in TV dumping conflict as of April, 2004

lexicographic statements about options; and manual ranking, using a process called fine tuning or direct ranking (Fang et al., 2003a). Here, we combine option prioritizing and direct ranking to estimate the state ranking for each DM.

CNTVs most prefer DOC to cancel the initial ruling; secondly they would like DOC to decrease the anti-dumping tariff. Based on this information, three groups of states are identified: $G_1 = \{s_3, s_6, s_9\}$, $G_2 = \{s_2, s_5, s_8\}$, and $G_3 = \{s_1, s_4, s_7, s_{10}\}$, with $G_1 \succ G_2 \succ G_3$. Then, direct ranking is carried out within G_1, G_2, and G_3. In G_1, the ranking is $s_3 \succ s_9 \succ s_6$. In G_2, the ranking is $s_2 \succ s_8 \succ s_5$. In G_3, the ranking is $s_1 \succ s_7 \succ s_4 \succ s_{10}$. Therefore, the ranking of all ten states is $s_3 \succ s_9 \succ s_6 \succ s_2 \succ s_8 \succ s_5 \succ s_1 \succ s_7 \succ s_4 \succ s_{10}$

CNG did not want to levy retaliatory duties and exacerbate the conflict. Based on this information, two groups are identified: $G_1 = \{s_1, s_2, s_3\}$, $G_2 = \{s_4, s_5, s_6, s_7, s_8, s_9, s_{10}\}$. Direct ranking within G_1 and G_2 were carried out, resulting in the overall ranking is $s_3 \succ s_2 \succ s_1 \succ s_9 \succ s_6 \succ s_8 \succ s_5 \succ s_7 \succ s_4 \succ s_{10}$.

DOC most prefers that CNTVs withdraw from the dispute. Secondly it would like to drop the anti-dumping duties to appease China. Based on this information, three groups are identified: $G_1 = \{s_{10}\}$, $G_2 = \{s_1, s_2, s_4, s_5, s_8\}$, and $G_3 = \{s_3, s_6, s_7, s_9\}$. Similarly, the overall ranking is $s_{10} \succ s_2 \succ s_5 \succ s_8 \succ s_1 \succ s_4 \succ s_3 \succ s_6 \succ s_9 \succ s_7$.

4.3.2 Equilibria and Evolution of the Conflict

Figure 15 shows all equilibria calculated according to different solution concepts. But state 10 is not an attainable equilibrium since no decision maker can move to it. CNTVs and CNG prefer the equilibrium at State 3 over State 10 because CNTVs and CNG want to fight the initial DOC ruling. Otherwise, there is no benefit from the TV export trade, and CNTVs must withdraw from the US market. Furthermore, no other strong equilibrium can be threatened to force CNTVs to move to State 10. Even though DOC most prefers the equilibrium at State 10, there is no hope to achieve it. Therefore, State 3 is a compromise for all sides; with the support of CNG, CNTVs formally files against the DOC's initial ruling and DOC revises the initial ruling and drops the anti-dumping duties. This is what actually happened on April 13, 2004, so far as we know, no further action has been taken by any DM to change the situation.

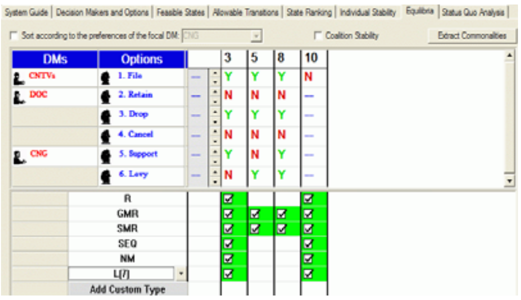

Figure 15 The equilibria of TV dumping conflict as of April, 2004

Decision Makers and Options	Status Quo State	Intermediate State		Equilibrium State
1. CNTVs				
(1) File	Y	Y	Y	Y
2. DOC				
(2) Retain	Y	Y	N	N
(3) Drop	N	N →	Y	Y
(4) Cancel	N	N	N	N
3. CNG				
(5) Support	Y	Y	Y	Y
(6) Levy	N →	Y	Y →	N
State Number	1	7	8	3

Figure 16 Moving from the status quo to the final equilibrium

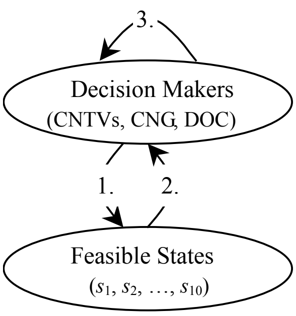

Figure 17 The ANP network for the TV dumping conflict

Figure 16 traces the evolution of the model from the status quo (State 1) to the final equilibrium (State 3). Starting at State 1 on the left, CNG supported CNTVs to file a suit against DOC, and warned of a possible retaliatory duty on TV exports to the US. Then the conflict moved from State 1 to State 7. DOC dropped the anti-dumping duties in the final ruling, which moved the model from State 7 to 8. Finally, CNTVs accepted this ruling and CNG cancelled the possible levy, causing the transition from State 8 to State 3, which is stable for all DMs and is therefore an equilibrium.

4.4 ANP Approach to Conflict Analysis

4.4.1 The Network Setting

Based on information provided in Section 4.2, there are ten feasible states and three DMs in the conflict. Figure 17 shows the network setting of this conflict.

4.4.2 Construction of the Supermatrix

First we estimate the inner priority matrix W_{NN}. We obtain the entries by answering the question: *For the other two DMs which DM has more influences on DM i, and how much more influence has it ?* (1-9 ratio data are used to represent the degree of influence) Table 2 shows the results. Based on this information, W_{NN} is shown in Table 3.

The priority matrix W_{SN} is obtained by answering the question: *For two feasible states, which is more preferred by DM i, and how much more preferred is it?*. The pairwise comparisons given CNTVs are listed in Table 4. Similarly, the pairwise comparisons of feasible states given CNG and DOC can be carried out to generate relative priorities. Then W_{SN} is set up and the results are shown in Table 5. The priority matrix W_{NS} is obtained by answering the question: *Given a feasible state* s_j, *which of two DMs prefers it more, and how much more preferred is it?*. Carrying out similar pairwise comparisons, the result of W_{NS} is listed in Table 6. Based on

Table 2 The inner pairwise comparisons

(CNTVs)	CNG	DOC	Weights
CNG	1	5	0.833
DOC	1/5	1	0.167
(CNG)	CNTVs	DOC	Weights
CNTVs	1	3	0.75
DOC	1/3	1	0.25
(DOC)	CNTVs	CNG	Weights
CNTVs	1	1/5	0.167
CNG	5	1	0.833

Table 3 The inner impact matrix W_{NN}

	CNTVs	CNG	DOC
CNTVs	0	0.75	0.167
CNG	0.833	0	0.833
DOC	0.167	0.25	0

4.4.3 Obtain the Limiting Supermatrix and Global Priority Vector

This information the supermatrix W is constructed and the results are given in Table 7.

Three typical value combinations of α_1 and α_2 are set for use with the weighted supermatrix, and the limiting supermatrices are calculated. The values of the global priority vectors are shown in Table 8. In all situations s_3 has the greatest value among the ten states. As can be seen, s_3 is the most stable state (equilibrium) for this conflict. This coincides with the GMCR II finding.

4.4.4 Comparison and Interpretation

ANP and the graph model employ different techniques to analyze the conflict model. Some distinct features and results of comparison are summarized as follows:

(1) ANP and the graph model can identify the same state: s_3 Note that the DMs' preference information about state rankings in ANP and GMCR II are consistent. For example, CNTVs' state ranking in GMCR II is $s_3 \succ s_9 \succ s_6 \succ s_2 \succ s_8 \succ s_5 \succ s_1 \succ s_7 \succ s_4 \succ s_{10}$ which is consistent with the ANP analysis results shown in Table 4. Therefore, based on consistent preference information, ANP and the graph model can generate similar results.

Table 4 The pairwise comparisons of feasible states

(CNTVs)	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}	Weights
s_1	1	1/4	1/7	3	1/2	1/5	2	1/3	1/6	5	0.04
s_2	4	1	1/4	7	3	1/2	5	2	1/3	8	0.114
s_3	7	4	1	8	5	3	6	4	2	9	0.278
s_4	1/3	1/7	1/8	1	1/4	1/7	1/2	1/6	1/8	2	0.019
s_5	2	1/3	1/5	4	1	1/4	3	1/2	1/6	4	0.053
s_6	5	2	1/3	7	4	1	5	3	1/2	8	0.154
s_7	1/2	1/5	1/6	2	1/3	1/5	1	1/4	1/6	3	0.029
s_8	3	1/2	1/4	6	2	1/3	4	1	1/4	5	0.080
s_9	6	3	1/2	8	6	2	6	4	1	7	0.218
s_{10}	1/5	1/8	1/9	1/2	1/4	1/8	1/3	1/5	1/7	1	0.016

Table 5 The impact matrix W_{SN}

	CNTVs	CNG	DOC
s_1	0.04	0.167	0.079
s_2	0.114	0.016	0.211
s_3	0.278	0.192	0.034
s_4	0.019	0.274	0.059
s_5	0.053	0.021	0.152
s_6	0.154	0.038	0.030
s_7	0.029	0.083	0.016
s_8	0.080	0.029	0.106
s_9	0.218	0.058	0.029
s_{10}	0.016	0.122	0.283

Table 6 The impact matrix W_{NS}

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
CNTVs	0.143	0.258	0.637	0.136	0.122	0.655	0.238	0.258	0.648	0.091
CNG	0.571	0.105	0.258	0.625	0.320	0.250	0.625	0.105	0.230	0.218
DOC	0.286	0.637	0.105	0.238	0.558	0.095	0.136	0.637	0.122	0.691

Table 7 The supermatrix

	CNTVs	CNG	DOC	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
CNTVs	0	0.75	0.167	0.143	0.258	0.637	0.136	0.122	0.655	0.238	0.258	0.648	0.091
CNG	0.833	0	0.833	0.571	0.105	0.258	0.625	0.320	0.250	0.625	0.105	0.230	0.218
DOC	0.167	0.25	0	0.286	0.637	0.105	0.238	0.558	0.095	0.136	0.637	0.122	0.691
s_1	0.04	0.167	0.079	0	0	0	0	0	0	0	0	0	0
s_2	0.114	0.016	0.211	0	0	0	0	0	0	0	0	0	0
s_3	0.278	0.192	0.034	0	0	0	0	0	0	0	0	0	0
s_4	0.019	0.274	0.059	0	0	0	0	0	0	0	0	0	0
s_5	0.053	0.021	0.152	0	0	0	0	0	0	0	0	0	0
s_6	0.154	0.038	0.030	0	0	0	0	0	0	0	0	0	0
s_7	0.029	0.083	0.016	0	0	0	0	0	0	0	0	0	0
s_8	0.080	0.029	0.106	0	0	0	0	0	0	0	0	0	0
s_9	0.218	0.058	0.029	0	0	0	0	0	0	0	0	0	0
s_{10}	0.016	0.122	0.283	0	0	0	0	0	0	0	0	0	0

Table 8 The global priority vectors

	The global priority vector V_∞		
	$\alpha_1 = \alpha_2 = 0.5$	$\alpha_1 = 0.9, \alpha_2 = 0.1$	$\alpha_1 = 0.1, \alpha_2 = 0.9$
CNTVs	0.2294	0.332	0.1724
CNG	0.2729	0.4068	0.1781
DOC	0.1643	0.1703	0.1757
s_1	0.034	0.009	0.0045
s_2	0.033	0.008	0.054
s_3	0.061	0.018	0.079
s_4	0.0444	0.0128	0.0562
s_5	0.021	0.005	0.036
s_6	0.025	0.007	0.035
s_7	0.016	0.0046	0.0203
s_8	0.022	0.006	0.034
s_9	0.035	0.01	0.048
s_{10}	0.042	0.01	0.067

(2) The graph model is a game-theory-related approach which employs solution concepts based on human behaviour listed in Table 1, to determine the stability of states. ANP is a decision science approach which constructs the influence supermatrix to generate the limiting state(s). The results can be regarded as non-myopic solutions in Table 1. The graph model more closely mimics how people actually behave under conflict, while ANP depends more on subjective judgments which involve experts' experience and knowledge.

(3) The graph model requires only ordinal preference information, essentially orderings of a finite number of states, and does not rely on cardinal preference information, which is usually hard to measure precisely. ANP requires the cardinal information obtained using pairwise comparisons to generate global cardinal priority information. Because of its lower information requirement, the graph model is easier to implement. The decision support system, GMCR II allows users to enter conflict models conveniently and expeditiously.

(4) The graph model can indicate the evolution of a conflict: how a conflict model moves from the status quo to the final equilibrium as listed in Figure 16. ANP can furnish cardinal information about the relative strengths of both DMs and feasible states. For example, V_N give the relative influences of DMs participating in the conflict. As can be seen in Table 8, CNG has the greatest influence on other DMs, indicating that CNG has the most power to control the evolution of the conflict. This is consistent with the evolution indicated by the graph model in Figure 16.

5. Conclusions

In this paper, a comparison study of ANP with the graph model is carried out using the China-US TV dumping conflict. The graph model and ANP constitute two distinctively different techniques. A key advantage of the graph model is that only rudimentary information is required to calibrate a model and execute an exhaustive stability analysis: the DMs; the options controlled by each DM; and ordinal preference information. The decision support software GMCR II operationalizes the modeling and analysis processes based on the graph model technique.

ANP, on the other hand, is a decision analysis technique for ranking or choosing alternatives. It focuses on analyzing the global priorities of different elements in the system based on pair-wise comparisons. It does not focus on the investigation of evolution, but rather adapts expert knowledge to give subjective judgments and generate overall results. As shown in the case study, these two methods can be employed in a complementary fashion to increase understanding of a strategic conflict.

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