CONFLICTS RESOLUTION AS A GAME WITH PRIORITIES: MULTIDIMENSIONAL CARDINAL PAYOFFS, PART 1

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Abstract

There are two ways to consider increasing the effectiveness of the theory of games in applications. The first is to derive priorities for the payoffs using a cardinal absolute relative scale instead of an ordinal or interval scale to do equilibrium analysis. Our approach using cardinal payoffs is illustrated with one example in an application to OPEC strategies that the author published in the International Journal of Game Theory. Ross Cressman in his book, Evolutionary Dynamics and Extensive Form Games, says that it is inconceivable that current decisions do not depend in an intricate manner on choices made in previous encounters. Such intricate choices can be included in the extensive form of a game, by not explicitly in its normal form. We show how such complex influences can be used in non-cooperative situations using priorities to prescribe best outcomes for the Palestinian-Israeli conflict and for the best strategy for the U.S. in Iraq.

1. Introduction

Analysis of equilibria in game theory is based on ordering pairs of strategies according to preference and assigning ordinal numbers accordingly. Often the ordinals are assigned intensities to indicate the degree of preference of one strategy, an intangible, over another, hoping to approximate to a cardinal expression of preference. However assigning such numbers is a fairly arbitrary and intuitive process that leaves one asking, is there a more scientific way to derive numbers to strategies that accords them a more accurate representation of an individual's preferences? How?

There is little doubt that our values and judgments help us determine the relative importance of the numbers we obtain through measurement and the more expert we are, presumably the closer we are to interpret the intensities of numbers in a valid way in so far as they represent the dominance of influences in the real world. The question then is whether any human being including an expert in any field including an individual who is untutored about numbers and arithmetic, has (or can have) the ability to evaluate the relative importance of the intensities of cardinal numbers. If we had such a cardinal representation of payoffs in game theory, how would the analysis of equilibria be theoretically different?

It is known to cognitive psychologists that making comparisons is an intrinsic biological talent that we have. In addition, this talent is used by all people no matter how educated or talented they are. Comparisons can be applied by an expert to derive relative numbers to represent their idea of relative importance or priority. To make sense of these priorities one must have corresponding feelings whose intensity more or less corresponds to the value of the numbers.

The Harvard psychologist Arthur Blumenthal tells us in his book *The Process of Cognition,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1977, that there are two types of judgment: "Comparative judgment, which is the identification of some relation between two stimuli both present to the observer, and absolute judgment, which involves the relation between a single stimulus and some information held in short term memory about some former comparison stimuli or

about some previously experienced measurement scale with which the observer rates the single stimulus."

In his book *The Number Sense, How the Mind Creates Mathematics*, the mathematician and cognitive neuropsychologist Stanislas Dehaene (Oxford University Press 1997, p.73) writes "Introspection suggests that we can mentally represent the meaning of numbers 1 through 9 with actual acuity. Indeed, these symbols seem equivalent to us. They all seem equally easy to work with, and we feel that we can add or compare any two digits in a small and fixed amount of time like a computer. In summary, the invention of numerical symbols should have freed us from the fuzziness of the quantitative representation of numbers."

Professor Michael Maschler the renowned game theorist and one of the editors of the International Journal of Game Theory recently wrote me: "People simply do not possess a utility function, or make mistakes when reporting their priorities. If you ask enough questions they will even state priorities that are not transitive. Thus, you cannot even determine a useful ordinal utility function. I do not know how to alleviate this difficulty. Therefore, at present, non-cooperative game theory can at best shed some insight on the real-life situation but usually it is not capable in suggesting definite recommendations (except for simple cases)".

Conflict resolution today has to be the most important subject for those who think about it and more urgently by those who deal with it as a practical matter on a daily basis [1]. The subject has been a main occupation in this author's career, from his days of working in disarmament in Washington, to teaching and writing [2,3] about the theory of games as a way to deal with conflicts, to many studies involving real political conflicts. Examples are Vietnam [2], terrorism in the Olympics [4], the conflict in Northern Ireland [5], the Middle East conflict, involving intensive meetings and discussions in Cairo, Egypt [6], in the early 1970s, and analysis of the conflict in South Africa in the 1980s [7], spurred by a conference in Pretoria in 1986 [8] resulting in a detailed analysis about the resolution of the conflict, commissioned by a government institute concerned with strategic studies. We need a practical quantitative approach that enables one to synthesize payoffs on different criteria. It delves in greater depth into the fine structures of strategies according to their merits and weaknesses when confronted with those of the opponent than does a game theoretic approach. It makes it possible for the parties to recognize and account for the strengths and weaknesses (political, military, social and so on) of their strategies against those of the opposition. The parties can work together through their representatives (perhaps often through the UN and in the presence of other parties to mitigate exaggerations and excessive claims) or do the analysis on their own with their own judgments partly imputed to what they think the opposition desires. In the absence of one party the judgments are surmised by the analyst from publicly declared positions and subjected to sensitivity analysis in case of uncertainties. In this manner one can evaluate the strategies of each party according to its merits against the strategies of the opponent(s) to improve the parties' understanding of the conflict in which they are involved. This type of analysis involves multi-criteria decisions with intangible payoffs derived from paired comparisons of the relative merits of the strategies against each of the opponent's strategies and then synthesizing the outcome across all merits and weaknesses, analyzed in short, medium and long range time frames.

Traditionally, conflicts have been analyzed quantitatively, using the normal form of a game, with payoffs of different strategies all played at the same time that often need to be measured in different ways [9]. We have a choice to make among the numbers we use to represent these payoffs [10]. Commonly, because of the complexity entailed in different kinds of measurement, ordinal numbers are used to indicate only that one payoff is larger than another [11]. But we can use stronger numbers, cardinal numbers, whose relative magnitudes are meaningful, particularly those

used to measure priorities among the things that are traded off. These numbers can be used to measure different things and are then synthesized into a single overall outcome. Theoretical considerations and calculations which appear impossible with ordinal numbers become possible with cardinal numbers. The preliminary steps to understanding the nature of a particular conflict are: 1. Identify the parties to the conflict. 2. Identify the objectives, needs, and desires of each of the parties. 3. Identify possible outcomes of the conflict and possible "solutions." 4. Clarify the assumptions about the way in which each party views its objectives and, in particular, its view of the relative importance of these objectives and the varying, possibly multidimensional, payoffs for these objectives. 5. Set out these assumptions so each party can view the outcomes and the way in which a given outcome might meet their objectives. This seemingly simple set of steps presents some difficulties, since the perceptions of different parties may differ sharply. "One of the very interesting problems in the study of "perception" and one which is still largely unsolved is of the conditions under which "perceptions" of different individuals converge under the impact of symbolic communication and the conditions under which they diverge" [12].

In practice, as part of the negotiating tactic, parties often do not like to sit facing each other and cooperate to resolve the conflict. This is often a consequence of the fear that they might reveal something that gives the other side an advantage. This, of course, need not always be an issue for representatives of nations in conflict, as their decisions can be vetoed by their leaders back home. More important, mediators and arbitrators are frequently used as buffers who can convey a most agreeable attitude in explaining a tough line or laying out the opening position of each party. Most non-cooperative conflicts are helped by the presence of a third party or organization called in to assist. The mediators' concern with balancing and creating a fair result should outweigh their strict concern for impartiality. The mediators must be careful that their impartiality does not lead them to play into the hands of the stronger party and, similarly, an analyst who desires to model a current conflict and who seeks information from concerned parties runs the risk of allowing his or her formulation to be biased by his understanding of the situation. Even apparently unbiased observers tend to have a slanted view.

Another problem that arises with regard to actual measurement on different scales is how to make comparable assessments made by different players. The relative values obtained for one individual may not be commensurate with the relative values obtained by another individual and the solution then would be to embed the two individuals in a larger framework to determine the commensurability of their relative values. This problem of embedding is a special case of considering both individuals in a single framework with feedback that makes it possible to combine their separate beliefs and influences to obtain a single best outcome in which the question of commensurability is now no longer a pressing issue. Within that framework it is possible to assess the relative importance of the individuals according to various criteria of influence, and also by considering the priorities of their interactions, and the relative importance of their value systems. The outcome is then the one that is best in taking into account their separate points of view.

Thus *a major problem in analyzing conflicts in quantitative terms is how to deal with the measurement of intangible factors that arise in a conflict.* In the past, people have talked around intangibles and have mostly decided not to include them, as dealing with intangibles can be highly subjective. MacKay [13] writes that pursuing the cardinal approaches is like chasing what cannot be caught. But the situation has changed since he wrote that because of the development of theories for deriving relative measures for intangibles such as the Analytic Hierarchy Process. Without measures for the intangibles, there is likely to be a lack of agreement on trading off values among the parties in the conflict. *While each party can reduce the tradeoffs to a single best outcome according to its system of priorities, it remains difficult to trade off values among several parties because of their differing values and objectives. In that case one must find an abstract way to*

define an index for tradeoffs among the parties that would be hard to reject on grounds of equality and fairness. In this paper, we will propose a way to do that.

Using ordinal payoffs in conflict resolution runs the risk of being arbitrary, because it attempts to summarize in a fell swoop many differing payoffs on different dimensions into a single ordinal number for each party and, in general, that is impossible to do, whether each payoff is expressed with cardinal (ratio scale) numbers or with ordinal numbers on the different dimensions. This is very similar to the problem of multi-criteria decision-making that deals with combining measurements of both tangible and intangible criteria, and we propose an extension of how we deal with it in decision-making theory to conflict resolution.

Decision problems have elements that belong to different domains of knowledge: economic, social, physical, political, environmental, and technological. In each of these areas influences are studied through analysis, by breaking a problem down into components and determining the effects and priorities of the factors involved. The question is how to synthesize this information into a holistic overall outcome that combines all the influences from the different domains. Whereas analysis solves a problem in well defined ways, synthesis leads to compromises across the different fields by prioritizing the importance of their factors relative to each other with respect to higher values and goals that deal with them all at once. Compromise is made according to the particular values and preferences of the people involved. Analysis is needed to study the parts; synthesis is needed to bring together what is known about the parts into a whole. How to model this mathematically has been of considerable interest to some applied mathematicians, economists and operations researchers around the world in recent years.

In this paper we show without too much detail, how to derive payoffs in the form of priorities by developing a hierarchic structure in which the goals and values of the players are represented and use judgments, hopefully provided by the players or surmised from their known positions and writing about them. We then use the Nash equilibrium approach to determine best outcomes in the case of OPEC versus the United States.

2. The Quantitative Approach to Conflict Resolution

Decision making and conflict resolution are intimately related. The first deals with best choices by reconciling the multiple values of a single individual and the second by finding an agreed upon outcome to reconcile the values of many. In both cases one seeks the best outcome. The best-known quantitative approach for reconciling the different values of the parties in order to produce a fair resolution to a conflict is the theory of games, which is an abstract approach in search of equilibria for conflicts studied in terms of opposing strategies of several players [14].

The payoffs are usually represented by a single number for each party. These numbers are given by the parties (or assigned by the analyst) as rough estimates for opposing strategies matched in pairs and laid out in a matrix, mostly using ordinal numbers, particularly when dollars or other types of cardinal numbers are unavailable or not easily known. The purpose is to find a strategy that is overall optimal for all the parties, that is finding a cell in the matrix such that if either party moves to a different cell by changing strategy, the opponent can also change strategy to make the first party's payoff less [15]. The strategy oriented *normal form* of a game – a single matrix of pairs of numbers- over the more complex extensive form gives the mathematician an easy notation for the study of *equilibria* problems, because it bypasses the question of how *strategies* are put together, i.e. how the game is actually played. The concept of Nash equilibrium falls in this class of equilibria for non-cooperative games. John Nash made significant contributions to both non-

cooperative game theory and to bargaining theory. He proved the existence of a strategic equilibrium for non-cooperative games - the Nash equilibrium - and proposed the "Nash program", in which he proposed dealing with cooperative games via their reduction to non-cooperative form. In his papers on bargaining theory, he founded axiomatic bargaining theory, and proved the existence of the Nash bargaining solution that was the first execution of the Nash program.

There have not been any other effective quantitative ways to analyze conflicts outside the ordinal equilibrium concepts of game theory [16]. When diverse multi-criteria measurements are available, they are assigned to the payoffs by the parties who have their own value systems. When the parties cooperate they can conceivably align their values (one of yours is worth two of mine). Is there any other way to obtain a best solution? One needs a credible way to combine the payoffs using cardinal measurements into a single overall outcome for each party.

For emphasis, we note again that if there are payoffs that result from a complexity of combinations of different components on different scales of measurement (as a payoff may be composed from factors that have different scales of measurement such as a war that involves money, the lives of people, cultural and social and political influences), it would generally not even be possible to combine them if one were to use ordinals, a question not addressed by game theory, which assumes that a wholesale hypothetical ordinal number can be assigned as the payoff. The idea of equilibrium would undoubtedly involve greater refinement if it were possible to use cardinal instead of ordinal numbers. The question then is what is gained from using cardinal numbers that is stronger than simply using equilibrium solutions. Were one to use cardinal instead of ordinal payoffs, can one obtain a better concept of solution other than the usual game theoretic one with ordinal payoffs? How would the solution be derived and its stability tested in that case?

The Analytic Hierarchy Process (AHP), and its generalization to dependence and feedback the Analytic Network Process (ANP), deal with measuring intangibles in conflicts in a cognitive rather than abstract fashion by deriving priorities of influence for the parties and for the effectiveness of their strategies from actual numerical measurements and from absolute judgments expressed numerically in a pairwise comparison process provided by the parties themselves or by experts knowledgeable about the conflict. The focus is on obtaining accurate judgments that reflect the relative intensity of dominance from which the priorities on which the analysis is based are derived. The analysis is done separately in terms of benefits, opportunities, costs, and risks and then combining them into a single best outcome. Sensitivity analysis is then used to test the stability of the outcome in ranges of values of the priorities derived for different ranges of values of the pairwise judgments. A significant concern is how to incorporate the judgments of different people without the requirement of consensus and how to also include different weights of importance (priorities) for the different judges who provide the judgments. Theorems have been proved to determine methods of synthesis to apply under such circumstances. Several conflicts have been studied in this way and the results communicated to the parties. The best known of these is the analysis of the conflict in South Africa in the 1980s that showed one of the best actions would be to release Nelson Mandela and to remove apartheid, both of which were done in the resolution that followed. Others instances where this approach was applied were terrorism in the Olympics, the conflict in Northern Ireland, the Middle East conflict, the compromise reached between Egypt and Israel in the late 1970s, and the ongoing U.S.- Iraq, China-Taiwan, and U.S.-North Korea conflicts.

In the next sections (3 and 4) we elaborate respectively on Game Theory with its ordinal approach to equilibrium and the AHP with its cardinal multicriteria approach. In section 5, we apply the AHP as a way of deriving cardinal priorities. We then parallel the discussions in these two sections, combining them in section 5 by using a game-theoretic equilibrium approach with the

OPEC problem. In section 6 we show how priorities derived with AHP can be used to alert parties in the conflict in Northern Ireland as to what the highest priority strategies they have to pursue resolution of that conflict.

3. The Theory of Games; A Normative Theory of Conflict Resolution

The major normative, what-should-be theory that deals with a formalization of the resolution of conflicts is the theory of games. It offers solutions that are thought to be mathematically best in some sense. It is concerned with games of strategy, a well-known rational way to deal with only certain kinds of conflict. Not all conflicts can be formalized as games of strategy and resolved normatively. Its approach requires that strategies be identified in order to think about how to resolve conflicts.

Game theory studies conflict and cooperation by considering the number of players, their strategies and payoffs [17, 18]. Games have been classified as cooperative and non-cooperative and analyzed according to the degree of information available to the players. A game is played with pure and with randomized strategies. The players seek to maximize the expected value of their payoffs. For non-cooperative games the Von Neumann minimax theorem for two-person zero-sum games proves that every finite zero-sum two-person game has a solution in mixed strategies. In 1950 John F. Nash extended this theorem to the existence of a solution of an n-person constant sum game in mixed strategies as a Nash Equilibrium solution. The Prisoner's Dilemma and Chicken are two non-cooperative games that do not yield satisfactory equilibrium solutions, and thus more than the existing concepts of equilibrium is still needed to obtain a good solution for them.

For cooperative games, von Neumann and Morgenstern introduced the idea of a characteristic function of a game and of the worth achievable by a coalition of some of the players independently of the remaining players [9]. A solution is called a stable set with which is associated a core. The core may not always exist. But when it does, it can have a nucleolus, all of which contain the idea of solution to the cooperative game. Many alternative solution concepts have been proposed to deal with coalitions. The Shapely value is another approach to solving a cooperative game. This value sometimes belongs to the core of the game. How to calculate an equilibrium solution can involve nonlinear techniques that may be approximate.

Payoff and expected payoff are central concepts in game theory. But payoff is measured according to what and whose values? How are the values obtained, and are they unique or are there other measures of payoff and do they all yield the same solution? Is it possible to resolve conflicts by other theoretical means that do not parallel the game theoretic approach with multi-dimensional measurements?

An intriguing problem in game theory is the assumption that it is possible to estimate payoffs for strategies in a game before the strategies of one player have been matched against those of the opponent in actual competition. Except for the simplest and most transparent situations it is impossible to spell out all the moves and tactics of a real-life strategy to really get a good idea of how well it would fare in competition. Some broad qualities of a strategy may be known, but exact prescriptions of its effectiveness may encounter such unanticipated problems in practice that it may be difficult to get a "good" estimate of its worth when compared with other strategies.

4. A Descriptive Theory of Conflict Resolution; AHP/ANP

Our mind interacts with the real world in two different quantitative ways of measurement. The first is simple and easier to do and that is to determine which of two elements *A* and *B* has a property more than the other and simply indicate for example that *B* has it more than *A* [19]. In addition if there are several such elements and one wishes to rank them one may use ordinal numbers of any magnitude to indicate their order. There is the possibility that one may make an error in such estimates and thus the outcome may not be exactly as it is in reality. The second relies on our ability to differentiate between magnitudes when the elements are closer with respect to the property and say with a fair amount of certainty approximately how many times more one element has the property than the other (the lesser one used as the unit). This is a much more difficult task that has many uncertainties. However, if one were to use the judgment of someone who has long term familiarity with the elements, an "expert", one may wish to take that cardinal route simply to see what kind of outcome it leads to and how reliable it is. That approach is no longer simply a less reliable way of guessing at numbers. It is now a well grounded querie that has been developed in considerable mathematical depth and applied to numerous real life situations, and one might add successfully.

Conflict resolution can be regarded as a multiparty, muticriteria and multiperiod (short medium and long term outcomes) decision-making process that involves use of prioritization in the context of benefits, opportunities, costs and risks. From the field of behavioral economics that imports insights from psychology into economics, one learns that conflict resolution is also an evolutionary process of learning to enrich the structure of factors included in the framework of analysis and the interaction and influence of these factors on the outcome with the passing of time. There are many conflict situations in which the grievance that a party has against another party or parties cannot be described in terms of strategies and in terms of responses to these strategies. A helpless person may have many creative and rational complaints against society but has no meaningful strategy to act on his/her grievances if indeed he/she who may also be crippled and inarticulate can. In other words not every wrong in the world can be formed as a game of strategy. Thus conflicts that can be formalized in terms of opposing strategies are a special case of conflicts in general. It is known that non-cooperative games do not always have an equilibrium solution for all the parties involved and these are the most intractable and pressing kinds of conflict including terrorism as a special case. The question is whether there is a way to formalize conflicts rationally in order that one may consider their solution without recourse to the idea of strategy where there may be no strategy, or when there is one, to analyze it as a particular case of a more general concept? It is easy to give examples of conflicts where no solution is possible. In a hungry society with little food to go around, the hungry would be opposed to the well fed for the threat of their survival. With increasing population and despite creativity and progress it may be that the world would reach a point where not all essential amenities would be potentially available to every one.

Let us look at some concepts developed in the AHP/ANP about conflict resolution and how they were applied in practice that take into consideration: multiple payoffs to each party, cooperation and non-cooperation, and the question of priorities for each party that need not be compatible with the priorities of their opponents, and how they were used in practice. The AHP/ANP evolved out of my experience at the Arms Control and Disarmament Agency (ACDA) in the Department of State during the Kennedy and Johnson years. ACDA negotiated arms agreements with the Soviets in Geneva. I was invited to join ACDA, I think because of work I had done for the military using Operations Research mathematics. I published on it and wrote the first book on mathematical methods of operations research. At ACDA I supervised a team of foremost internationally known scientists, economists and game theorists (coincidentally including four people who later won the Nobel Prize in economics: Debreu, Harsanyi, Selten and Aumann) who

advised ACDA on arms tradeoffs, but we had some insurmountable difficulties in making lucid and usable recommendations to our highly intelligent and experienced negotiators who were guided by strong intuition deriving from long practice.

We consider three types of uses of measurement. One is a strict game theoretic context. The other is a game against nature and the third is an equilibrium game with gains and losses. We don't think that it is possible to present the entire details of the conflicts involved but only to give the reader an idea of a new area of possibilities for conflict resolution.

5. OPEC

Here we analyze the relative effectiveness of the strategies if engaged against each strategy of the opponent. This yields a vector of the relative strengths of the strategies against each strategy of the opponent's. These vectors form the columns of a matrix. Each row of this "engagement" matrix is weighted by the corresponding "intrinsic" weight of the strategy from the first step to obtain the payoff matrix. The process is repeated to obtain the opponent's payoff matrix.

The next steps in the process are as follows:

1. Construct a hierarchy of objectives and strategies for each actor.
2. Prioritize these objectives.
3. Compute "constant values" of each actor's strategies; for example, the relative effectiveness of each strategy in satisfying the actor's objectives.
4. Compute "current values" of the strategies; for example, the relative strengths of the strategies of one actor against those of the opponent.
5. Compute the payoffs to each actor by multiplying the current value of each strategy by its constant value. This results in a payoff matrix showing the payoffs to the actors for each pair of their strategies.
6. Search for a "Nash equilibrium solution."

The objective of the method is first to assign payoffs to the strategies of the actors by taking into consideration both their "constant" and their "current" values and then to determine the equilibrium solution (s).

The United States may choose one or a mix of the following strategies [20]:

U_1: Reduce oil imports from OPEC by increasing imports from non-OPEC oil producers, accelerating the development of indigenous resources, and reducing oil consumption.
U_2: Limit petroleum imports by tariffs and quotas.
U_3: Prepare an emergency scheme for dealing with sudden oil shortages, such as establishing strategic petroleum reserves, oil rationing programs, and emergency oil sharing.
U_4: Devalue the dollar against other major currencies.
U_5: Take military action against OPEC.
U_6: Impose embargoes of various kinds of goods and services to OPEC.
U_7: Weaken or break up OPEC by a joint consumer action.
U_8: Help Israel in its confrontations with the Arabs.
U_9: Encourage and support a "just" political settlement of the Arab-Israeli conflict.
U_{10}: Increase interdependence with OPEC members.
U_{11}: Increase arms sales to OPEC members.

OPEC members, either individually or collectively, may choose one or a mix of the following strategies:

O_1: Impose an oil embargo.
O_2: Cut back production.
O_3: Base the price of oil on the nearest alternative energy source.
O_4: Link crude oil prices to an index of prices of goods that OPEC members need to import.
O_5: Reduce the price of oil drastically
O_6: Use SDRs (Saudi Dinars) or a basket of majorindicator.
O_7: Increase oil prices gradually.
O_6: Impose sudden oil price hikes.
O_9: Search for an alternative to OPEC.
O_{10}: Increase interdependence with the oil importers.
O_{11}: = Do nothing.

Table 1 Payoffs to U.S. and OPEC by Matching their Strategies

	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	O_9	O_{10}	O_{11}
U_1	6.6,0	12,1.2	14,0	10,1.1	5.6,.6	9.7,0	13,0	8.2,0	19,.35	3.5,3.5	17,.28
U_2	.22,.14	.25,2.5	.26,.42	.25,.65	2.8,0	.59,.76	.41,.25	.17,.4	.37,.38	0,3.3	.34,0
U_3	3,0	2.6,0	.78,.26	0,2.9	.35,0	.49,.46	.34,1.3	.71,0	1.2,.5	0,6	1.2,5
U_4	0,0	.14,1.1	0,.65	0,9.3	0,0	0,2.3	.47,.44	.43,.34	0,.32	0,.27	0,0
U_5	.02,.51	0,2.3	0,0	0,0	0,0	0,.39	0,0	0,0	0,0	0,1.8	0,0
U_6	.05,.24	0,1.1	0,0	0,0	0,0	0,.54	0,0	0,.15	0,0	0,7.1	0,0
U_7	6,.05	.79,2	1.1,0	.52,.67	.45,0	.31,0	.75,0	.99,.43	0,.57	0,1.4	0,0
U_8	.02,.51	0,1.1	0,0	0,0	0,0	0,.39	0,0	0,.93	0,0	0,0	0,0
U_9	2.6,0	0,0	0,0	0,6.3	0,0	0,0	0,1.6	0,0	0,0	4.3,7.9	0,.12
U_{10}	2.3,0	2.7,0	2.7,0	6.9,2.8	3.5,0	7.6,0	4.3,0	6.1,0	3.8,3.2	9.2,7.9	4.6,.12
U_{11}	0,0	0,0	0,0	.31,6.2	.31,0	0,0	0,8.5	0,0	0,0	0,0	0,.22

The payoff matrix of the U.S.-OPEC conflict is given in Table 1. The (U_i, O_j) entry in the matrix represents the payoff to the United States if it adopts strategy U_i, and to OPEC if it adopts strategy O_j. These payoffs are obtained by weighting each current value (the relative strength of the strategies of one actor against those of the opponent) by the constant value (the relative effectiveness of each strategy in satisfying the actors' objectives) of the corresponding strategy.

The next step is to find the Nash equilibrium solution of the nonzero sum U.S.-OPEC game. The Nash equilibrium solution is a pair of strategies (one for each player) such that no player is able to improve his payoff by changing his strategy choice while the other player holds his strategy fixed. In our case the solution is (U_{10}, O_{10}); that is, to increase interdependence between the United States and OPEC members.

Increasing interdependence between the oil consumers and oil producers appears to be a rational strategy. By exercising restraint in price hikes and by investing in the economies of the oil-consuming countries, particularly the United States, OPEC members are encouraging this type of outcome. (U_{10}, O_{10}) places the United States in a good position against threats by OPEC members regarding production cutbacks and oil price hikes. It also boosts U.S. exports, thereby providing more jobs and improving the U.S. balance of payments. From the OPEC members'

viewpoint, interdependence not only ensures an oil market but also provides OPEC countries with U.S. technology, capital, and management skills needed for development.

Looking at the equilibrium solution (U_{10}, O_{10}), which deals with interdependence, we see that the payoff for the United States is higher than that for OPEC ($U_{10} = 9.2$, $O_{10} = 7.9$). This is because the oil producers, with their large oil revenues, should be able to buy capital, technology, and know-how almost anywhere. The United States, however, does not have a wide choice for its oil imports. With interdependence, the U.S. is benefited more than OPEC.

If other consumers were to follow a policy of interdependence, the difference between the two payoffs (of producers and consumers) would be drastically reduced. This is because each oil consumer would be tied to several oil producers, which would reduce the chances of OPEC members switching customers. (A Pareto-optimal point has a payoff not worse for each coordinate than that of any other point).

If the "interdependence" strategies of the United States and OPEC (U_{10}, O_{10}) are removed, we would have several Pareto-optimal points at (U_{11}, O_4), (U_1, O_2), (U_1, O_1), and (U_1, O_9), Among these points, only (U_1, O_2) is an equilibrium solution, with the United States reducing its dependence on OPEC by increasing its imports from non-OPEC sources, accelerating the development of indigenous resources, and reducing oil consumption through energy conservation; and OPEC cutting back production in order to prevent a glut in the oil market due to reduced demand for its oil and to keep the Price of oil from falling. Note that in the (U_1, O_2) equilibrium, OPEC's payoff has decreased more than six times while the U.S. payoff has increased slightly.

If the strategies with U_{10}, O_{10} and U_1, O_2 are eliminated, there would be no equilibrium solution in single strategies, and the likelihood of conflict of interest between OPEC members and oil consumers, particularly the United States, would be great. That would bring losses to all the actors in the international oil market. We could calculate the expected value of each strategy by summing and normalizing the row (column) payoffs to the U.S. (OPEC).

Two points have been illustrated in this section. The first is how to derive payoffs in the form of priorities on a relative scale of absolute numbers instead of attaching ordinals and the second is to use the idea of Nash equilibrium to determine the best strategies for the players. This is a good way to deal with situations where everything is known in advance by all the parties and they are fairly sure about their strategies and payoffs. In real life the situation is often different.

6. Unilateral Approach that Includes Opponents' Concerns

Fudenberg and Levine [21] in their book The Theory of Learning in Games, write that traditional explanation of equilibrium is that it results from analysis and introspection by the players in a situation where the rules of the game, the rationality of the players, and the player's payoff functions are all common knowledge. Both conceptually and empirically, these theories have many problems." They go on to say that they deal with situations in which the players are less than fully rational, who grope for optimality over time and the learning models they use do not lead to any equilibrium beyond the very weak notion of rationalizability. It is along similar lines that the real life applications described below were made (see also Elster [22]).

In our last example about the US-OPEC relations we had Nash equilibria to determine the best outcome by using the normal form of a game. But Nash equilibria do not always exist and often one is faced with trading off not strategies but move within a strategy thus requiring

something like the extensive form of a game, a general approach is needed to enable one to resolve a conflict based on tradeoffs among payoffs within and between strategies in an appropriately determined sequential way.

The best way to illustrate this approach is through an example. It illustrates how the use of priorities helps the player to discover how important in the general scheme of things they and their strategies are thus tempering the degree and intensity of credible claims they can make. By knowing that often the parties have resorted to extremes like terrorism to increase their relative power as in Northern Ireland, in the Balkans and in the Middle East.

The Northern Ireland Conflict

An early application of the AHP was made in 1977 to the conflict in Northern Ireland [23,24]. This early analysis was repeated over the years as the situation changed [24]. These studies created a great deal of interest in official as well as in academic circles. Alexander was invited to present her work on Northern Ireland in Canada and the People's Republic of China, as well as in Northern Ireland. In the United States, she made presentations on these studies at the Pentagon and at West Point, in addition to a number of academic venues.

In 2004, a further study using the AHP looked at the attitudes to the ongoing problems of Northern Ireland shown by the Scotch-Irish (Ulster-Americans), and compared what they wanted to happen with what they thought actually would happen [24]. A presentation based on this paper was given at the Ulster American Heritage Symposium in Northern Ireland, where it aroused considerable interest.

A number of the insights derived from the earlier studies seemed to have an effect on the way in which the respondents in the latest study viewed the problem, particularly in their assessment of the relative power of the participants in the conflict.

The first step in each analysis was to identify the participants to the conflict, those individuals or groups who may have an influence on the outcome. The problem is often described in religious terms, although this is a gross over-simplification. Throughout, there was a conscious effort to use basic descriptors and to avoid terms that used religious denominations, in order to remove any potential prejudice. This approach owes much to the influence of Richard Rose, who defined the Northern Ireland problem in classical political science terms of allegiance (or non-allegiance) to a regime.

To ensure that assumptions made in the analyses were valid, Alexander spent a number of extended periods in Northern Ireland to study the problems at first hand. She met with political, church, and community leaders, who gave generously of their time and who seemed pleased to discuss a wide range of issues. We are grateful to these busy people for their help.

The main participants in the Northern Ireland conflict are:

The British Government (BRITAIN), which controls Northern Ireland.
The Protestant (Unionist) majority community (ALLEGIANTS), which wants Northern Ireland to remain separate from the Republic of Ireland and which would find a substantial measure of minority participation acceptable. (This group does not include those who support violence.)

The Loyalist groups (DEFENSE), whose needs are similar to those of the ALLEGIANTS, but who are prepared to use force to resist the creation of a United Ireland.
The Roman Catholic (Nationalist) minority community (MODERATES), which includes both those who would prefer to join Northern Ireland with the Republic of Ireland and those who would be content to have Northern Ireland remain separate, provided that a structure that provides for substantial minority participation is established. (This group does not include those who support violence.)
The Irish Republican Army (IRA) (which includes not only the Provisional and Official subgroups and their supporters, but also the so-called splinter groups), which considers violence to be an acceptable path to a United Ireland.
The Government of the Republic of Ireland (DUBLIN), which seeks to act on an equal footing with the British Government in determining what should happen in Northern Ireland. It also aspires to a United Ireland.

The list of objectives of each participant is long: the reader is referred to Alexander 2004 and to the earlier studies.

The current political structure in Northern Ireland is that set up by the Belfast Agreement (Good Friday Agreement) of 1998, i.e., an elected Assembly with built-in guarantees of participation by all major groups in the ruling Executive. Cross-border bodies are, in theory, responsible to the elected Assembly in Belfast and the Dail (parliament) in Dublin. (In practice, these cross-border bodies seem to be under the control of London and Dublin.) The British Government is ultimately in control of Northern Ireland, with considerable input from the Irish Government.

Some of the citizens of Northern Ireland would like to be ruled directly by the British Government with a fully integrated Parliament, on the same basis as other regions of the United Kingdom (with the exception of Scotland and Wales, both of which have a considerable measure of autonomy). Others want Northern Ireland to be joined with the Republic of Ireland in a unitary state.

A further option, for which there is a measure of support, is for Northern Ireland to become a separate state, independent of both Britain and the Republic of Ireland. This could be, for example, a state within the (British) Commonwealth or it could be a state within the European Union.

Thus, the possible Political Outcomes* [24] are:

(a) the Good Friday Agreement: AGREEMENT
(b) an Integrated Parliament: INT-PARLIAMENT
(c) a separate independent state: INDEPENDENCE
(d) union of Northern Ireland and the Republic of Ireland: UNITED-IRELAND

* In the 1977 and subsequent studies, two outcomes of an elected Assembly, with or without a Council of Ireland, were listed. In the 2004 study, the Good Friday Agreement replaced these outcomes since the Agreement included an elected Assembly.

In the two studies of the Northern Ireland conflict carried out in 1977 [23], Alexander and Saaty showed that the most likely outcome would be some form of legislative independence for Northern Ireland, followed closely by a local Assembly. This suggested that a strong local Assembly, with a considerable measure of autonomy, would provide a workable solution. Since this outcome might well satisfy the MODERATES, but would certainly not satisfy the IRA and would probably not satisfy DUBLIN, it was reasonable to ask if a change in the relative power of these two participants relative to the remaining participants would affect the outcome and, if so, how much of a change would be necessary. By using what is known as the backward process through the hierarchy and varying the power of the participants, they were able to find thresholds of power to indicate by how much the power of both the IRA and DUBLIN would have to be increased relative to the other participants to change the outcome.

It now appears that these increases in power may have been achieved, at least in the eyes of the respondents in the 2004 study. In this latest study, the AGREEMENT outcome came out first, but barely ahead of the UNITED IRELAND outcome, using the probabilities obtained from the AHP analysis. When asked to rank their personal preferences, however, the group ranked the AGREEMENT first and the UNITED IRELAND outcome last. The respondents considered it desirable for the people of Ulster (Northern Ireland) to remain separate from the Republic of Ireland. They understood and sympathized with the desire of their kinsmen not to be absorbed into an all-Ireland state. Nevertheless, they saw the power of both the IRA and DUBLIN as having been so enhanced over recent years that their influence was now considerable. They saw the forces arrayed against the Ulster majority as being so powerful that the probability that a United Ireland will occur is now almost as great as the probability of successful implementation of the Good Friday Agreement.

The use of the AHP to analyze this problem enables one to shed light on a complex problem. The respondents in the 2004 study had no previous experience with a study of this nature, but were able to make straightforward comparisons and thus enable the analyst to calculate the required probabilities. The sharp dichotomy between what they saw as desirable and what emerged from their answers in the AHP part of the study seems to show that their personal preferences did not influence their judgments on the comparison weights.

What of the future? The situation described is volatile and the end result may not be the triumph of violence suggested by the latest study. Ongoing analyses of this problem may provide further understanding.

7. Conclusion

So far we have dealt with conflicts in terms of equilibria to resolve a conflict or in terms of priorities of strategies within hierarchic structures to enable players to assess their relative power and what they can and cannot achieve against their opponents. Particularly in the application to the conflict in Northern Ireland, it was possible to inform one of the parties about what it could not accomplish because of its low priority of influence relative to the other parties and the options it had to increase its effectiveness.

In the next paper we explore a different way of conflict resolution by giving examples that use network structures with dependence and feedback to derive different kinds of payoffs involving benefits, opportunities, costs and risk and then combine them into an overall payoff used to determine the best strategy to follow or to tradeoff different moves in a strategy to benefit the

parties according to balance between their own value systems rather than according to an overall abstract strategic equilibrium.

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