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DECISION MAKING WITH THE ANALYTIC NETWORK PROCESS

Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks

by

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PREFACE

Applications of the Analytic Network Process (ANP) in decision making demonstrate to our considerable amazement, and by way of validation, that people as they experience life know far more about the world in which they live and more accurately than language alone allows them to express. Logic follows language in developing its analytical details. When we make decisions across the boundaries of different areas of information we need a way to synthesize priorities in addition to using analysis and applying judgments in each area to create these priorities. It is synthesis that is needed to make good decisions. The network structures used in the context of benefits, opportunities, costs and risks (BOCR) make it possible to identify, classify and arrange all the factors and interests that influence the outcome of a decision. A decision is only as good as the framework we use to represent its clusters, their elements and the connections we identify among them that depict the influences we perceive.

Both the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) were conceived and their theoretical underpinnings were developed by T.L. Saaty, and there is now an international society on the subject that meets every two years under the name of ISAHP (International Symposium on the Analytic Hierarchy Process). The theory of the ANP was first introduced and simply illustrated in Chapter 8 of Saaty's 1980 book Multicriteria Decision Making: The Analytic Hierarchy Process which was then followed in 1996 by Decision Making with Dependence and Feedback revised in 2001 to include BOCR and finally in 2005 to include negative priorities and different formulas for synthesis in Theory and Applications of the Analytic Network Process.

As with our other coauthored book, Decision Making in: Economic, Political, Social and technological Environments with the Analytic Hierarchy process, 2001, about applications of hierarchies in decision making; this book is about applying network structures with dependence and feedback in decisions. It is a collection of selected applications of the ANP to economic, social and political sciences, and technological design. The chapters are comprised of contributions made by scholars working with the first author and by graduate student in classes on the Analytic Network Process taught by him. Our friendship has often brought us together to carry out a project that would be onerous for one person to do alone. We enjoy thinking of the topics, motivating the works and performing the task of collecting and bringing together what appears to us to be of potential interest to readers and users of the Analytic Network Process worldwide. Most of these studies have been edited and shortened but their essence preserved. We believe that the ANP is a general tool that is helpful in assisting the mind to organize its thoughts and experiences and to elicit judgments recorded in memory and quantify them in the form of priorities, and allow for representing diverse opinions after discussion and debate.

The reader will notice that many of the chapters were developed by more than one person. We have observed that Co-authorship of the papers and reports is useful for debating judgments that may otherwise appear too subjective and idiosyncratic. Those authors often studied the literature to find out what the real actors in a problem thought and inferred their judgments from this knowledge.

We have been particularly interested in three themes: economics, the social sciences and the linking of measurement with human values. The ANP offers economists a very different approach for dealing with economic problems than the usual mathematical models on which economics bases its quantitative thinking: utility theory (with its interval scales and its use of gambles or lotteries to elicit judgments from decision makers) and linear programming which can only work on elements that already have measurement scales. The variety of examples included here can perhaps stimulate some readers to try applying the ANP approach that is based on the much stronger, absolute scales used to represent pairwise comparison judgments in the context of dominance with respect to a property shared by the homogeneous elements being compared. How much or how many times more does A dominate B with respect to property P? Actually people are able to answer this question by using words to indicate intensity of dominance that all of us are equipped biologically to do all the time (equal, moderate, strong, very strong and extreme) whose conversion to numbers, validation and extension to inhomogeneous elements form the foundation of the AHP/ANP. Priorities are then derived from the totality of the judgments.

The second theme is concerned with the social sciences. The ANP offers psychologists, sociologists and political scientists the methodology they have sought for some time to quantify and derive measurements for intangibles. We hope that the examples included in this book will entice them to study the theory. It should quickly become clear that the ANP is the kind of instrument they have been seeking.

The third theme is concerned with providing people in the physical and engineering sciences with a quantitative method to link hard measurement to human values. In such a process one is able to interpret the true meaning of measurements made on a uniform scale using a unit. Measurements on such scales are only indicators of the state of the system; they often do not relate directly to the values of the human observers of the system.

The variety in this book has been greatly enhanced by the availability of the SuperDecisions software (www.superdecisions.com), the personal computer implementation of the ANP that is now used fairly widely by decision makers, consultants, teachers and students in business and engineering schools.

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CHAPTER 1

THE ANALYTIC NETWORK PROCESS

Thomas L. Saaty

1. INTRODUCTION

Analysis to break down a problem into its constituent components to study their behavior has been the major tool of scientific inquiry to test hypotheses and solve problems. It has proven to be extremely successful in dealing with the world of matter and energy. It has enabled man to land on the moon, to harness the energy of the atom, to master global communication, to invent the computer and to produce tens of thousands of useful and not so useful things. But it has not been so effective in the world of man. Transportation is a socio-technical problem and not a purely technical one as the moon journey was. How clean should the environment be depends on our expectations and on the limited resources we have. But our expectations have no limits imposed on them. Socio-technical problems are not "solved" in the strict sense that purely technical problems are. Solution here means that a reasonable compromise among various requirements is reached. The best solution may not be the best technical, or best economic, or best political or social even though it must consider all of them. Thus, analysis that partitions a problem into its components cannot forge the proper compromise solution to socio-technical questions. What is needed is a method of *synthesis*, to form the whole from the parts. It must enable one to deal with the different values and objectives, prioritizing their relative importance by looking ahead to forge a best compromise answer according to the different parties and influences involved and the values they have. Synthesis is the subject of the theory of this chapter supported by numerous applications in the rest of the book (Zandi, 1975).

There are two known ways to analyze causal influences and their effects. One is by using traditional deductive logic beginning with assumptions and carefully deducing an outcome from them. This is a linear and piecemeal approach in which several separate conclusions may be obtained and the problem is to piece them together in some coherent way which needs imagination and experience as logic tells us little or nothing about how to bring the different conclusions into an integrated outcome.

The other is a holistic approach in which all the factors and criteria involved are laid out in advance in a hierarchy or in a network system that allows for dependencies. All possible outcomes that can be thought of are joined together in these structures and then both judgment and logic are used to estimate the relative influence from which the overall answer is derived. This approach requires knowledge and experience with the subject, and is not totally dependent on the ability to reason logically which most people cannot do well anyway and

which is not guaranteed to discover the truth because the assumptions may be poor, and the reasoning faulty. Feelings and intuition play at least as important a role in deciding the outcome as the ability to reason precisely and deduce unerringly. It may be that some matter of low importance that is determined with logical certainty is found to be cumulatively influential because of its indirect relationship with other important factors. This approach generally leads to a sound overall outcome about the real world.

People who work in decision making have been concerned for a long time with the measurement of both physical and psychological events. By physical we mean the realm of what is known as *tangibles* in so far as they constitute some kind of objective reality outside the individual conducting the measurement. By contrast, the psychological to which judgments used in decision making belong, is the realm of the *intangibles*, comprising the subjective ideas, feelings, and beliefs of an individual, of a group working together, and more generally of society as a whole. The question is whether there is a coherent theory that can deal with both these worlds of reality without compromising either. The Analytic Hierarchy Process (AHP) is a method that can be used to establish measures in both the physical and social domains.

The AHP is a general theory of measurement. It is used to derive relative priorities on absolute scales (invariant under the identity transformation) from both discrete and continuous paired comparisons in multilevel hierarchic structures. These comparisons may be taken from actual measurements or from a fundamental scale that reflects the relative strength of preferences and feelings. The AHP has a special concern with departure from consistency and the measurement of this departure, and with dependence within and between the groups of elements of its structure. It has found its widest applications in multicriteria decision making (Saaty and Alexander, 1989) in planning (Saaty and Kearns, 1985) and resource allocation (Saaty, 2001, 2005), and in conflict resolution. In its general form, the AHP is a nonlinear framework for carrying out both deductive and inductive thinking without use of the syllogism. This is made possible by taking several factors into consideration simultaneously, allowing for dependence and for feedback, and making numerical tradeoffs to arrive at a synthesis or conclusion.

In using the AHP or its generalization to feedback networks, the Analytic Network Process (ANP) to model a problem, one needs a hierarchic or a network structure to represent that problem, as well as pairwise comparisons to establish relations within the structure.

Paired comparison judgments in the AHP/ANP are applied to pairs of homogeneous elements. In all the examples in this book, the judgments used to perform the comparisons are not purely the preferences of the authors, but are frequently tantamount to expert judgments. They represent their best understanding of the influences involved from the different parties' points of view, as surmised from the literature, the parties' points of view expressed in the media and occasionally, when possible, by consulting the parties themselves.

Sensitivity analysis is used to analyze the effects of variations in judgments on the stability of the final outcome.

The fundamental scale of values to represent the intensities of judgments is shown in Table 1. This scale has been derived through stimulus response theory and validated for effectiveness, not only in many applications by a number of people, but also through theoretical justification of what scale one must use in the comparison of homogeneous elements.

Table 1. The Fundamental Scale of Absolute Numbers

Intensity of Importance	Definition	Explanation
1	**Equal Importance**	Two activities contribute equally to the objective
2	Weak	
3	**Moderate importance**	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	**Strong importance**	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	**Very strong or demonstrated importance**	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	**Extreme importance**	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	**If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i***	A reasonable assumption
Rationals	**Ratios arising from the scale**	If consistency were to be forced by obtaining *n* numerical values to span the matrix

There are many situations where elements are equal or almost equal in measurement and the comparison must be made not to determine how many times one is larger than the other, but what fraction it is larger than the other. In

other words there are comparisons to be made between 1 and 2, and what we want is to estimate verbally the values such as 1.1, 1.2, ..., 1.9. There is no problem in making the comparisons by directly estimating the numbers. Our proposal is to continue the verbal scale to make these distinctions so that 1.1 is a "tad", 1.3 indicates moderately more, 1.5 strongly more, 1.7 very strongly more and 1.9 extremely more. This type of refinement can be used in any of the intervals from 1 to 9 and for further refinements if one needs them, for example, between 1.1 and 1.2 and so on.

An important aspect of paired comparisons is the reciprocal property. When one element is determined to be x times more dominant than another with respect to a given property, the lesser one is used as the unit and the larger is estimated to be some multiple of that unit. The inverse comparison is made by assigning the lesser element the reciprocal value $1/x$.

Validity of the outcome of decisions using the scale is illustrated by practical examples where actual measurements are known. Table 2 shows how an audience of about 30 people used consensus to combine each group judgment instead of the mathematically proven geometric mean. They provided judgments in verbal form to estimate the *dominance* of the consumption of drinks in the United States by answering the question: Which drink on the left (e.g., coffee) is consumed more in the US over the drink on the top (e.g., wine) and how much more than another drink? The derived vector of relative consumption and the actual vector, obtained by normalizing the consumption given in official statistical data sources, are at the bottom of the table.

Table 2. Relative Consumption of Drinks

Which Drink is Consumed More in the U.S.?
An Example of Estimation Using Judgments

Drink Consumption in the U.S.	Coffee	Wine	Tea	Beer	Sodas	Milk	Water
Coffee	1	9	5	2	1	1	1/2
Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	2	1	1/3	1/4	1/3	1/9
Beer	1/2	9	3	1	1/2	1	1/3
Sodas	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1

The derived scale based on the judgments in the matrix is:

Coffee	Wine	Tea	Beer	Sodas	Milk	Water
.177	.019	.042	.116	.190	.129	.327

with a consistency ratio of .022.

The actual consumption (from statistical sources) is:

.180	.010	.040	.120	.180	.140	.330

When we have several criteria to perform prioritization and obtain **synthesis**, we need to also compare the importance of the criteria with respect to higher level criteria or with respect to a goal to determine their priorities, and as above, derive priorities for the alternatives with respect to each criterion.

Finally, to obtain an overall ranking of the alternatives we multiply the normalized priorities of the alternatives by the corresponding normalized priorities of the criteria and add. This we also do for the criteria by using the priorities of higher level criteria (which in general we do in the same way by normalizing). This is called the **distributive** mode of the AHP. In it we assume, as often happens in practice, that an alternative depends on the number and quality of other alternatives with which it is compared. It is also used when the criteria also depend on the alternatives as in the ANP described below. If we wish to require for convenience in practice that the priorities of the alternatives should not be influenced by the number or quality of other alternatives, or if the criteria are not attributes directly related to the alternatives, then we use the ideal mode in which for each criterion we divide the priorities of the alternatives by the largest value among them and then multiply by the corresponding normalized priority of that criterion and add over the criteria. This is known as the **ideal** mode of the AHP. The ideal mode is also used in the ANP for each control criterion described below because the control criteria are needed to make paired comparisons and are not attributes of the alternatives whose priorities depend on the alternatives directly as in the ANP or indirectly (by comparing them with respect to a higher criterion or goal influenced by any existing or ideal alternative) as in the AHP.

World Chess Championship Outcome Validation of Measurement in a Hierarchy– Karpov-Korchnoi Match

The following criteria (Table 3) and hierarchy (Figure 1) were used to predict the outcome of world chess championship matches using judgments of ten grandmasters in the then Soviet Union and in the United States who responded to questionnaires they were mailed. The predicted outcomes that included the number of games played, drawn and won by each player either was exactly as they turned out to be or adequately close to predict the winner. The outcome of this exercise was officially notarized before the match took place. The notarized statement was later mailed to the editor of the *Journal of Behavioral Sciences* along with the paper (Saaty and Vargas, 1991). The prediction was that Karpov would win by 6 to 5 games over Korchnoi, which he did.

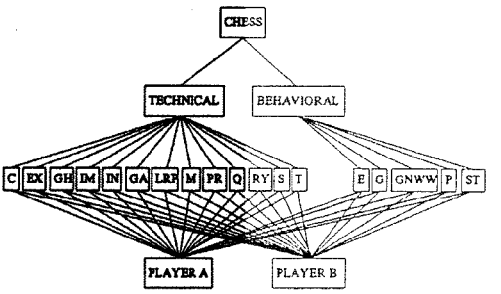

Figure 1. Criteria and Players in Chess Competition

Table 3. Definitions of Chess Factors

T (1)	*Calculation* (Q): The ability of a player to evaluate different alternatives or strategies in light of prevailing situations.
B (2)	*Ego* (E): The image a player has of himself as to his general abilities and qualification and his desire to win.
T (3)	*Experience* (EX): A composite of the versatility of opponents faced before, the strength of the tournaments participated in, and the time of exposure to a rich variety of chess players.
B (4)	*Gamesmanship* (G): The capability of a player to influence his opponent's game by destroying his concentration and self-confidence.
T (5)	*Good Health* (GH): Physical and mental strength to withstand pressure and provide endurance.
B (6)	*Good Nerves and Will to Win* (GN): The attitude of steadfastness that ensures a player's health perspective while the going gets tough. He keeps in mind that the situation involves two people and that if he holds out the tide may go in his favor.
T (7)	*Imagination* (IW): Ability to perceive and improvise good tactics and strategies.
T (8)	*Intuition* (IN): Ability to guess the opponent's intentions.
T (9)	Game Aggressiveness (GA): The ability to exploit the opponent's weaknesses and mistakes to one's advantage. Occasionally referred to as "killer instinct."
T (10)	*Long Range Planning* (LRP): The ability of a player to foresee the outcome of a certain move, set up desired situations that are more favorable, and work to alter the outcome.
T (11)	*Memory* (M): Ability to remember previous games.
B (12)	*Personality* (P): Manners and emotional strength, and their effects on the opponent in playing the game and on the player in keeping his wits.
T (13)	*Preparation* (PR): Study and review of previous games and ideas.
T (14)	*Quickness* (Q): The ability of a player to see clearly the heart of a complex problem.
T (15)	*Relative Youth* (RY): The vigor, aggressiveness, and daring to try new ideas and situations, a quality usually attributed to young age.
T (16)	*Seconds* (S): The ability of other experts to help one to analyze strategies between games.
B (17)	*Stamina* (ST): Physical and psychological ability of a player to endure fatigue and pressure.
T (18)	*Technique* (T): Ability to use and respond to different openings, improvise middle game tactics, and steer the game to a familiar ground to one's advantage.

2. THE ANALYTIC NETWORK PROCESS (ANP)

Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements on lower-level elements. Not only does the importance of the criteria determine the importance of the alternatives as in a hierarchy, but also the importance of the alternatives themselves determines the importance of the criteria. Two bridges, both strong, but the stronger is also uglier, would lead one to choose the strong but ugly one unless the criteria themselves are evaluated in terms of the bridges, and strength receives a smaller value and appearance a larger value because both bridges are strong. Feedback enables us to factor the future into the present to determine what we have to do to attain a desired future. Figures 2 and 3 below illustrate the difference between hierarchies and networks. A hierarchy is a linear top down structure. A network spreads out in all directions and involves cycles between clusters and loops within the same cluster (Saaty 1996, 2001, 2005).

The feedback structure does not have the linear top-to-bottom form of a hierarchy but looks more like a network, with cycles connecting its components of elements, which we can no longer call levels, and with loops that connect a component to itself. It also has sources and sinks. A **source** node is an origin of paths of influence (importance) and never a destination of such paths. A **sink** node is a destination of paths of influence and never an origin of such paths. A full network can include source nodes; intermediate nodes that fall on paths from source nodes, lie on cycles, or fall on paths to sink nodes; and finally sink nodes. Some networks can contain only source and sink nodes. Still others can include only source and cycle nodes or cycle and sink nodes or only cycle nodes. A decision problem involving feedback arises often in practice. It can take on the form of any of the networks just described. The problem is to determine the priorities of the elements in the network and in particular the alternatives of the decision. Because feedback involves cycles, and cycling can be an infinite process, the operations needed to derive the priorities become more demanding than has been familiar with hierarchies. Unraveling their intricacies is challenging to the intellect and is essential for making the computations precise.

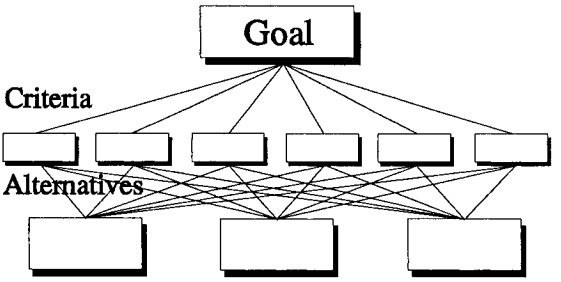

Figure 2. A three level hierarchy in detail

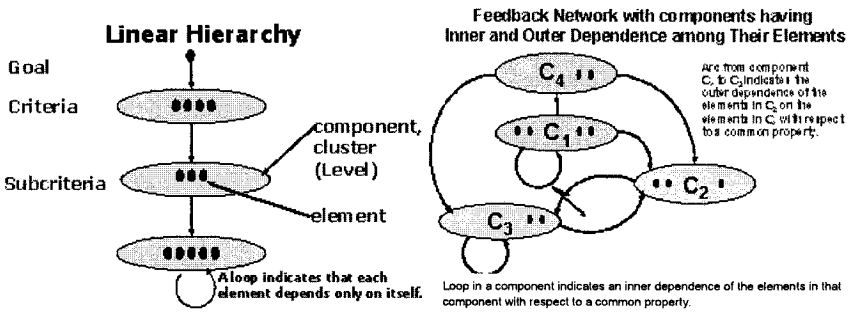

Figure 3. Structural Difference between a Linear and a Nonlinear Network

At present, in their effort to simplify and deal with complexity, people who work in decision making use mostly very simple hierarchic structures consisting of a goal, criteria, and alternatives. Yet, not only are decisions obtained from a simple hierarchy of three levels different from those obtained from a multilevel hierarchy, but also decisions obtained from a network can be significantly different from those obtained from a more complex hierarchy. We cannot collapse complexity artificially into a simplistic structure of two levels, criteria and alternatives, and hope to capture the outcome of interactions in the form of highly condensed judgments that correctly reflect all that goes on in the world. We must learn to decompose these judgments through more elaborate structures and organize our reasoning and calculations in sophisticated but simple ways to serve our understanding of the complexity around us. Experience indicates that it is not very difficult to do this although it takes more time and effort. *Indeed, we must use feedback networks to arrive at the kind of decisions needed to cope with the future.*

To test for the mutual independence of elements such as the criteria, one proceeds as follows: Construct a zero-one matrix of criteria against criteria using the number one to signify dependence of one criterion on another, and zero otherwise. A criterion need not depend on itself as an industry, for example, may not use its own output. For each column of this matrix, construct a pairwise comparison matrix only for the dependent criteria, derive the priority vector, and augment it with zeros for the excluded criteria. If a column is all zeros, then assign a zero vector to represent the priorities. The question in the comparison would be: For a given criterion, which of two criteria depends more on that criterion with respect to the goal or with respect to a higher-order controlling criterion?

In this chapter we lay out the theoretical foundations for the kinds of structures and matrices of derived scales associated with feedback networks from which we obtain the priorities for a decision. For numerous applications of the ANP the reader should consult the book called the Encyclicon (Saaty and Ozdemir, 2005).

3. THE SUPERMATRIX OF A FEEDBACK SYSTEM (Saaty, 2001, 2005)

Assume that we have a system of N components where the elements in each component interact or have an influence on some or all of the elements of another component with respect to a property governing the interactions of the entire system, such as energy or capital or political influence (see Figure 4).

In general, a network consists of components and elements in these components. But in creating structures to represent problems there may be larger parts to consider than components. According to size, we have a **system** that is made up of **subsystems**, with each subsystem made up of **components**, and each component made up of **elements**. We might consider that the whole need not be equal to the sum of its parts, but may, due to synergy, be larger or smaller in the sense of contributing to a goal. Sometimes we refer to a set of objects contained in a larger one as elements when in fact they may be components. The context would make this clear.

Note that the network connecting the components of a decision system must always be connected. It cannot be divided into two or more disconnected parts, otherwise they cannot communicate with each other and it is pointless to ask for the influence of one part on another because there can never be any.

There are three kinds of components in Figure 4.

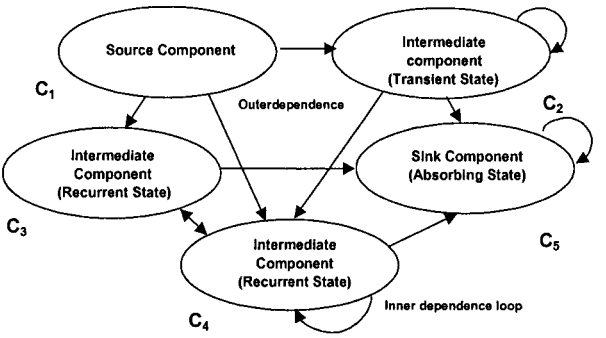

Figure 4. Types of Components in a Network

Those components which no arrow enters are **source** components such as C_1 and C_2. Those from which no arrow leaves are known as **sink** components such as C_5; and finally those which arrows both enter and exit leave are known as **transient** components such as C_3 and C_4. In addition, C_3 and C_4 form a **cycle** of two components because they feed back and forth into each other. C_2 and C_4 have **loops** that connect them to themselves. They are **inner dependent**. All other connections represent dependence between components that are thus known to be **outer dependent**. An example of dependence between components is the input-output of materials among industries. The electric industry supplies electricity to other industries including itself. But it depends more on the coal

industry than on its own electricity for operation and also more on the steel industry for its turbines.

We denote a component of a decision network by C_h, h = 1, ... m, and assume that it has n_h elements, which we denote by $e_{h1}, e_{h2}, \ldots, e_{hm_h}$. The influences of a given set of elements in a component on any element in the system are represented by a priority vector derived from paired comparisons in the usual way of the AHP. It is these derived vectors, how they are grouped and arranged, and then how to use the resulting structure which turns out to be a matrix, that interests us here. This matrix is thus used to represent the flow of influence from a component of elements to itself as in the loop that flows back to C_4 above, or from a component from which an arrow is directed out to another component. Sometimes, as with hierarchies, one is concerned with the influence of the component at the end of an arrow on the component from which the arrow begins; one must decide on one or the other. The influence of elements in the network on other elements in that network can be represented in the following **supermatrix:**

$$W = \begin{array}{c} \\ C_1 \\ \\ \\ C_2 \\ \\ \\ C_N \\ \\ \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & & C_2 & \bullet\bullet\bullet & C_N \\ e_{11}\, e_{12} \cdots e_{1n_1} & & e_{21}\, e_{22} \cdots e_{2n_2} & & e_{N1}\, e_{N2} \cdots e_{Nn_N} \end{array} \\ \begin{bmatrix} W_{11} & W_{12} & \bullet\bullet\bullet & W_{1N} \\ W_{21} & W_{22} & \bullet\bullet\bullet & W_{2N} \\ \vdots & \vdots & \bullet\bullet\bullet & \vdots \\ W_{N1} & W_{N2} & \bullet\bullet\bullet & W_{NN} \end{bmatrix} \end{array}$$

Figure 5. The Supermatrix of a Network

A typical entry W_{ij} in the supermatrix, is called a **block** of the supermatrix. It is a matrix of the form

$$\mathbf{W}_{ij} = \begin{bmatrix} W_{i1}^{(j_1)} & W_{i1}^{(j_2)} & \bullet\bullet\bullet & W_{i1}^{(jn_j)} \\ W_{i2}^{(j_1)} & W_{i2}^{(j_2)} & \bullet\bullet\bullet & W_{i2}^{(jn_j)} \\ \vdots & \vdots & \bullet\bullet\bullet & \vdots \\ W_{in_i}^{(j_1)} & W_{in_i}^{(j_2)} & \bullet\bullet\bullet & W_{in_i}^{(jn_j)} \end{bmatrix}$$

Each column of W_{ij} is a principal eigenvector of the influence (importance) of the elements in the *ith* component of the network on an element in the *jth*

component. Some of its entries may be zero corresponding to those elements that have no influence. Thus we do not need to use all the elements in a component when we make the paired comparisons to derive the eigenvector, but only those that have a non-zero influence. Figures 6 and 7 and their accompanying supermatrices represent a hierarchy and a holarchy of m levels. As with any supermatrix, an entry in each of the foregoing two supermatrices is a block W_{ij} positioned where the ith component or level is connected to and influences the jth level immediately above. The entry in the last row and column of the supermatrix of a hierarchy is the identity matrix I. It corresponds to a loop at the bottom level, used to show that each element depends only on itself. It is a necessary aspect of a hierarchy (or any sink) when viewed within the context of the supermatrix. The entry in the first row and last column of a holarchy is nonzero because the top level depends on the bottom level.

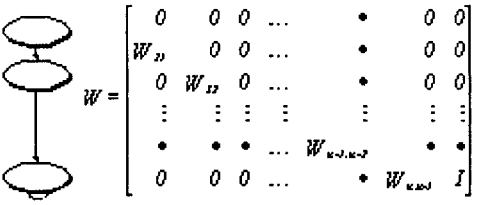

Figure 6. The Structure and Supermatrix of a Hierarchy

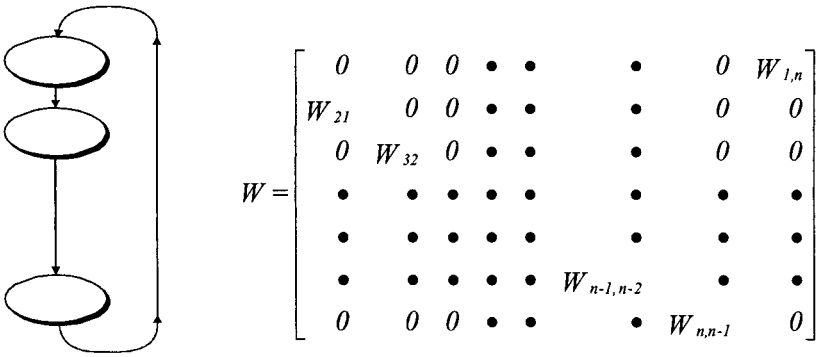

Figure 7. The Structure and Supermatrix of a Holarchy

A network may be generated from a hierarchy by increasing the hierarchy's connections gradually so that pairs of components are connected as desired and some components have an inner dependence loop.

4. The Control Hierarchy And What Question To Ask

For clarity and greater precision, the influence represented in all the derived eigenvectors of priorities entered in a supermatrix must be measured according to a single criterion, such as economic influence. Another supermatrix may represent social influence, and so on. We call such criteria with respect to which influence is represented in individual supermatrices **control criteria**. Because we need to combine all such influences obtained from the limits of the several supermatrices in order to obtain a measure of the priority of **overall influence**, we need to group the control criteria in a structure that allows us to derive priorities for them and use these priorities to weight the corresponding individual supermatrix limits and add. Such a structure of control criteria may itself be elaborate. For simplicity we call the structure of control criteria a **control hierarchy**. Analysis of priorities in a system can be thought of in terms of a control hierarchy with dependence among its bottom-level alternatives arranged as a network (Figure 6). Dependence can occur within the components and between them. A control hierarchy at the top may be replaced by a control network with dependence among its components. More generally, one can have a cascading set of control networks, the outcome of one used to synthesize the outcomes of what it controls. For obvious reasons relating to the complexity of exposition, apart from a control hierarchy, we will not discuss such complex control structures here. A control hierarchy can also be involved in the networks of its criteria with feedback involved.

A component in the ANP is a collection of elements whose function derives from the synergy of their interaction and hence has a higher-order function not found in any single element. A component is like the audio or visual component of a television set or like an arm or a leg, consisting of muscle and bone, in the human body. A mechanical component has no synergy value but is simply an aggregate of elements and is not what we mean by a component. The components of a network should generally be synergistically different from the elements themselves. Otherwise they would be a mechanical collection with no intrinsic meaning.

We make the observation that the criteria in the control hierarchy that are used for comparing the components are usually the major parent criteria whose subcriteria are used to compare the elements in the component. Thus the criteria for comparing the components need to be the same or more general than those of the elements because of the greater functional complexity of the components.

There are two types of control criteria (subcriteria). A control criterion may be directly connected to the structure as the goal of a hierarchy if the structure is in fact a hierarchy. In this case the control criterion is called a comparison-"linking" criterion. Otherwise, a control criterion does not connect directly to the structure but "induces" comparisons in a network and hence, it is called a comparison-"inducing" criterion.

The **generic question** to be answered by making pairwise comparisons is: Given a control criterion (subcriterion), a component (element) of the network,

and given a pair of components (elements), how much more does a given member of the pair influence that component (element) with respect to the control criterion (subcriterion) than the other member?

5. The Benefits, Costs, Opportunities And Risks And Their Merit Ratings

Any decision has several favorable and unfavorable **concerns** to consider. Some of these are sure things, others are less certain and have a likelihood of materializing. The favorable sure concerns are called **benefits** while the unfavorable ones are called **costs**. The uncertain concerns of a decision are the positive **opportunities** that the decision might create and the negative **risks** that it can entail. Each of these four concerns utilizes a separate structure for the decision, beginning with a benefits control structure and the network of interdependencies that belongs under each benefit control criterion, and ending with a risks control structure. We refer to the four concerns collectively as **BOCR** merits, having used the initials of the positive ones (benefits and opportunities) before the initials of the negative ones (costs and risks). Each of these concerns contributes to the merit of a decision and must be evaluated (rated) individually on a set of (prioritized) criteria that is used to also rate any other decision. We call these ratings **merits** and refer to the evaluation criteria to derive them as **strategic criteria**. Examples of strategic criteria are: satisfaction, happiness, convenience, fulfillment, order, harmony, peace, power, efficiency, social good, progress, wealth and so on. They must themselves be prioritized for frequent use in all decisions. In this manner we can synthesize the outcome of the alternatives for each of the BOCR structures, to obtain their **overall synthesis**. We note that for costs and risks one must ask which is more costly and which is more risky (not which is less costly and which is less risky) because in paired comparisons we can only estimate how much more the dominant member of a pair has a property as a multiple of how much the less dominant one has it and not the other way around. The priorities of the alternatives are now synthesized by using a marginal formula BO/CR and a total outcome or global one bB+oO-cC-rR. The priorities b, o, c, and r are obtained by rating the B, O, C and R one at a time with respect to strategic criteria as the applications make clear. The rating is carried out by synthesizing the priorities of the alternatives (given in ideal form) with respect to each of the control criteria for which a network is constructed for each of the B, O, C and R merits, and using the top rated alternative in the rating of that merit (Saaty, 2001). Also note that the total outcome formula is related to the residual probabilities formula that always gives positive answers: $bB + oO + c(1\text{-}C) + r(1\text{-}R) = bB + oO - cC - rR + c + r$ in which the costs and risks are subtracted from one and in the end it turns out that the same constant $c + r$ is added to the priority of every alternative. However, this last formula may be useful in situations involving BOCR that predict proportionate voting or other type of outcomes measured with positive numbers or statistics.

6. PRIORITIES IN THE SUPERMATRIX

We are interested in deriving limit priorities of influence from the supermatrix. To obtain such priorities the supermatrix must first be transformed to a matrix each of whose columns sums to unity, known as a *column stochastic* or simply a **stochastic** matrix. *If the matrix is stochastic, the limit priorities can be viewed in a way to depend on the concepts of reducibility, primitivity, and cyclicity of the matrix* (the details not needed here are discussed in Saaty (2005) and Saaty (2001) in the text and in an appendix). Note that in applying the ideas, the reader will only need to structure a decision problem and provide the necessary judgments as instructed or coached by the powerful software SuperDecisions (SuperDecisions, 2000) developed for this purpose. It is not mandatory to learn the details of the theory to apply it in practice.

The question arises as to whether there is a natural way (a scientific on top of a mathematical justification) to transform a given supermatrix whose columns usually sum to more than one, to a stochastic matrix. The priority of an element in a component is an inadequate indicator of its priority in the entire set of components. The highest priority element in a component need not be the highest priority element in the set of components. This is obvious because each component has a highest ranked element and they cannot all be first in the system. Thus we need to compare the components themselves according to their influence on each component in the supermatrix with respect to a higher order control criterion. The comparisons give rise to a derived vector of priorities of the influence of all the components (on the left of the supermatrix) on each component on top. This is done as many times as there are components. The resulting vectors are each used to weight the blocks of matrices that fall in the column under the given component. The first entry of the vector is multiplied by all the elements in the first block of that column, the second by all the elements in the second block of the column and so on. In this manner we weight the blocks in each column of the supermatrix. The result is known as the **weighted supermatrix** which is now stochastic. It is this stochastic matrix that we can work with to derive the desired priorities by transforming it to a **limit matrix** described below. This matrix yields the long-run or limit priority of influence of each element on every other element.

Remark: By way of further elaboration on rendering the supermatrix stochastic we note that it may be that only some elements of a component have an influence on some elements of another component in which case zeros are entered where there is no influence. Or it may even be that no element of a component influences a given element of another (there would be zeros for all the priorities represented by that vector) or only some elements influence it (there would be zeros for the priorities of the elements that do not influence it in the priority vector). In the case where an entire vector, but not all vectors in that component, is zero, the weighted column of the supermatrix must be renormalized. It is appropriate to say here that if all the elements of a

component have zero influence on all the elements of a second component, the priority of influence of the first component itself on the second must also be equal to zero. However, this is not true when some or all the elements of the first component have an influence on some or all of those of the second. That is why the renormalization of some columns is essential and natural in making the weighted supermatrix stochastic.

We note that if the component of the alternatives of a decision is a sink of the network, and the other components do not depend on it, it need not be included in the supermatrix, and its priorities are used in the process of synthesis after limit priorities have been obtained for the relevant components of the supermatrix. This enables one to ensure rank preservation when desired by using the ideal mode of the AHP. If the component of alternatives is not a sink then it must be kept in the supermatrix whose priorities are analogous to the distributive mode and hence rank may legitimately be allowed to reverse.

7. On The Limit Supermatrix And Its Cesaro Sum

Why do we need to raise the supermatrix to powers? It is because we wish to capture the transmission of influence along all possible paths of the supermatrix. The entries of the weighted supermatrix itself give the direct influence of any element on any other element. But an element can influence a second element indirectly through its influence on some third element and then by the influence of that element on the second. There are potentially many third elements. One must consider every such possibility of a third element. All indirect influences of pairs of elements through an intermediate third element are obtained by squaring the weighted supermatrix. Again the influence of one element on another can occur by considering a third element that influences a fourth element, which in turn influences the second element. All such influences are obtained from the cubic power of the matrix, and so on. Thus we have an infinite sequence of influence matrices: the matrix itself, its square, its cube, etc., denoted by W^k k=1,2,... . If we take the limit of the average of a sequence of N of these powers of the supermatrix (known as the Cesaro sum), $\lim_{k\to\infty} \frac{1}{N} \sum_{k=1}^{N} W^k$, does the result converge and is the limit unique? How do we compute this limit to obtain the desired priorities? It is known in mathematical analysis that if a sequence converges to a limit then its Cesaro sum converges to the same limit. Since the sequence is defined by the powers of the matrix, it is sufficient to find out what the limit of these powers is. It may well be that the sequence does not converge to a unique limit but its Cesaro sum averages out over the different limits of the sequence obtaining a unique limit. As we shall see, both these cases occur for our supermatrix when it is raised to powers. First we note from the Jordan Canonical Form of a stochastic matrix W that

$\lim_{k\to\infty}\frac{1}{N}\sum_{k=1}^{N}W^k$ generally exists. It is known that W is similar to its Jordan matrix J if there is a nonsingular matrix P such the $J=PWP^{-1}$. Thus raising W to limiting powers is equivalent to raising J to limiting powers. So what does J look like? With every square matrix is associated a unique Jordan matrix that has the following form: It consists of square blocks whose principal diagonals lie on its principal diagonal. All entries that lie outside these blocks are equal to zero. All entries that lie in a block are zero except for the principal diagonal all of whose entries are the same and are equal to an eigenvalue of W, and all entries in the diagonal immediately above the principal diagonal are equal to one. The matrix W is said to be the direct sum of its Jordan blocks. Without too much detail, it is clear that $\lim_{k\to\infty}\frac{1}{N}\sum_{k=1}^{N}W^k$ exists if: (a) no eigenvalue of W has modulus greater than one, (b) W has no eigenvalue of modulus one other than $\lambda=1$, and if $\lambda=1$ is an eigenvalue as it is with the stochastic matrix W, it has only 1-by-1 blocks in the Jordan Canonical Form. In fact one can define a limit in the sense of Cesaro when case (b) is not satisfied. To know that the limit exists and to derive that limit are different matters. We now derive this limit.

According to J.J. Sylvester one can represent an entire function of a (diagonalizable) matrix W whose characteristic roots are distinct as:

$$f(W)=\sum_{i=1}^{n}f(\lambda_i)Z(\lambda_i),$$

where

$$Z(\lambda_i)=\frac{\prod_{j\neq i}(\lambda_j I-W)}{\prod_{j\neq i}(\lambda_j-\lambda_i)}$$

The $Z(\lambda_i)$ can be shown to be complete orthogonal idempotent matrices of W; that is, they have the properties

$$\sum_{i=1}^{k}Z(\lambda_i)=I,\ Z(\lambda_i)Z(\lambda_j)=0,\ i\neq j,\ Z^2(\lambda_i)=Z(\lambda_i),$$

where I and 0 are the identity and null matrices, respectively. Thus for example if one raises a matrix to arbitrarily large powers, it is enough to raise its eigenvalues to these powers and form the above sum involving the sum of polynomials in W. Because the eigenvalues of a stochastic matrix are all less than one, when raised to powers they vanish except when they are equal to one or are complex conjugate roots of one. Because here the eigenvalues are assumed to be distinct, we have the simplest case to deal with, that is $\lambda_{max}=1$ is

a simple eigenvalue. Formally, because the right hand side is a polynomial in W multiplying both sides by W^{∞} each term on the right would be a constant multiplied by W^{∞} and the final outcome is also a constant multiplied by W^{∞}. Because we are only interested in the relative values of the entries in W^{∞} we can ignore the constant and simply raise W to very large powers which the computer program *SuperDecisions* does [8].

Next we consider the case where $\lambda_{\max} = 1$ is a multiple eigenvalue. For that case we have what is known as the confluent form of Sylvester's theorem:

$$f(W) = \sum_{j=1}^{k} T(\lambda_i) = \sum_{i=1}^{k} \frac{1}{(m_i - 1)!} \frac{d^{m_i - 1}}{d\lambda^{m_i - 1}} f(\lambda)(\lambda I - W)^{-1} \frac{\prod_{i=1}^{n}(\lambda - \lambda_i)}{\prod_{i=m_{i-1}}^{n}(\lambda - \lambda_i)}\Bigg|_{\lambda=\lambda_i}$$

where k is the number of distinct roots and m_i is the multiplicity of the root λ_i. However, as we show below, this too tells us that to obtain the limit priorities it is sufficient to raise W to arbitrarily large power to obtain a satisfactory decimal approximation to W^{∞}.

The only possible nonzero survivors as we raise the matrix to powers are those $\lambda's$ that are equal to one or are roots of one. If the multiplicity of the largest real eigenvalue $\lambda_{\max} = 1$ is n_1, then we have

$$W^{\infty} = n_1 \frac{\frac{d^{(n_1-1)}}{d\lambda^{(n_1-1)}}\left[(\lambda I - W)^{-1}\Delta(\lambda)\right]}{\Delta^{(n_1)}(\lambda)}\Bigg|_{\lambda=1}$$

where one takes derivatives of the characteristic polynomial of the matrix W, and $\Delta(\lambda) = \det(\lambda I - W) = \lambda^n + p_1\lambda^{n-1} + \ldots + p_n$. Also,

$(\lambda I - W)^{-1} = F(\lambda)/\Delta(\lambda)$ and

$$F(\lambda) = W^{n-1} + (\lambda + p_1)W^{n-2} + (\lambda^2 + p\lambda_1 + p_2)W^{n-3} + \ldots$$

$$+(\lambda^{n-1} + p_1\lambda^{n-2} + \ldots + p_{n-1})I$$

is the adjoint of $(\lambda I - W)$. Now the right side is a polynomial in W. Again, if we multiply both sides by W^{∞}, we would have on the right a constant multiplied by W^{∞} which means that we can obtain W^{∞} by raising W to large powers.

For the cases of roots of one when $\lambda_{max} = 1$ is a simple or a multiple root, let us again formally see what happens to our polynomial expressions on the right in both of Sylvester's formulas as we now multiply both on the left and on the right first by $\left(W^c\right)^\infty$ obtaining one equation and then again by $\left(W^{c+1}\right)^\infty$ obtaining another and so on c times, finally multiplying both sides by $\left(W^{c+c-1}\right)^\infty$. We then sum these equations and take their average on both sides. The left side of each of the equations reduces to W^∞ and the average is given by $\frac{1}{c}W^\infty$. On the right side the sum for each eigenvalue that is a root of unity is simply a constant times the sum $\left(W^c\right)^\infty + \left(W^{c+1}\right)^\infty + \cdots + \left(W^{c+c-1}\right)^\infty$. Also, because this sum is common to all the eigenvalues, it factors out and their different constants sum to a new constant multiplied by (1/c). This is true whether one is a simple or a multiple eigenvalue because the same process applies to accumulating its constants. In the end we simply have

$$\frac{1}{c}\left[\left(W^c\right)^\infty + \left(W^{c+1}\right)^\infty + \cdots + \left(W^{c+c-1}\right)^\infty\right] = \frac{1}{c}\left(1 + W + \cdots + W^{c-1}\right)\left(W^c\right)^\infty, c \geq 2,$$

that amounts to averaging over a cycle of length c obtained in raising W to infinite power. The cyclicity c can be determined, among others, by noting the return of the form of the matrix of powers of W to the original form of blocks of zero in W.

Caution: Some interesting things can happen in the limit supermatrix when $\lambda_{max} = 1$ is not a simple root. For example if we have multiple goals in a hierarchy that are not connected to a higher goal, that is if we have multiple sources, we may have several limit vectors for the alternatives and these must be synthesized somehow to give a unique answer. To do that, the sources need to be connected to a higher goal and prioritized with respect to it. Otherwise, the outcome would not be unique and we would obtain nothing that is meaningful in a cooperative decision (but may be useful in a non-cooperative problem where the goals for example, are different ways of facing an opponent). It is significant to note that a hierarchy always has a single source node (the goal) and a single sink cluster (the alternatives), yet its supermatrix is reducible. Only when the supermatrix is irreducible ($\lambda_{max} = 1$ is a simple root) and thus its graph is strongly connected with a path from any node or cluster to any other node or cluster that the columns of the supermatrix would be identical. It is rare that the supermatrix of a decision problem is irreducible. If the source clusters do not have sufficient interaction to serve as a single source, one could take the average of the alternatives relating to the several sources as if they are equally important to obtain a single overall outcome.

8. RATING

When one rates alternatives, they must be independent of one another. The presence or absence of an alternative must have no effect on how one rates any of the others. We call this kind of ranking of alternatives with respect to an ideal (which is an arbitrarily chosen fixed reference point) *absolute measurement* or *rating*. Absolute measurement is analogous to measuring something with a physical device; for example, measuring length with a yardstick.

In order to rate alternatives with respect to an ideal, we need to create intensity levels or degrees of variation of quality on a criterion; for example, excellent, above average, average, below average and poor. We then pairwise compare them to establish priorities and normalize those priorities by dividing by the largest value among them, so that *excellent* would have a value of 1.000 and the others would be proportionately less. Idealizing the priorities by dividing by the largest assures that intensities belonging to large families do not receive small priorities simply because there are many of them. We then rate an alternative by selecting the appropriate intensity level for it on each criterion. Even when we use a numerical scale, say 1 to 100, to rate each alternative we must have an intuitive idea of how high or how low an alternative falls and in the process we subconsciously make comparisons among different levels on the scale. It is not the exact number chosen, but the level of intensity of feeling behind where it should fall, up or down, on the scale that matters. Because it compares the alternatives with respect to a standardized ideal, absolute measurement is normative not descriptive.

The ratings approach is illustrated in the following example of choosing the best city to live in. Figure 8 shows the goal, criteria and their priorities obtained from paired comparisons, and the intensities for each criterion with their idealized values obtained by dividing by the largest value in the vector of priorities derived from their paired comparisons matrix.

The pairwise comparisons for the *Cultural* criterion intensities and the resulting priorities are illustrated in Table 4 below. The values in the *Idealized* column are obtained by dividing each priority in the *priorities* column by the largest, 0.569. The prioritized intensities become the standards from which one selects the appropriate one to describe a particular city's performance with respect to *Cultural* (interpret this as cultural opportunities). The prioritized intensities in essence become a standardized performance scale, something like a yardstick that can be used to rate a city on culture. Note that for this criterion of culture, judgment is still involved in deciding which intensity to pick. Actual data can also be used in establishing the priorities, usually involving some form of idealization where data is converted to priorities directly.

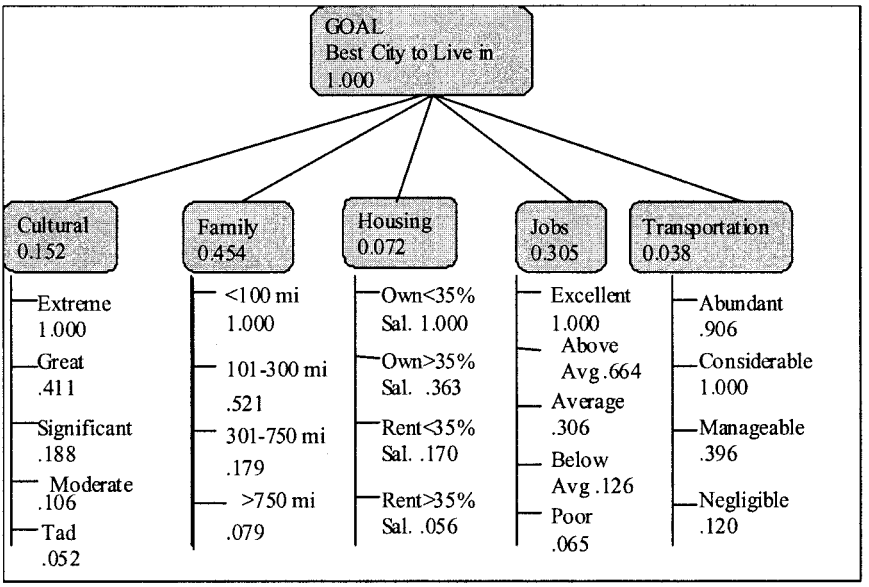

Figure 8. Most Livable Cities in the US

Table 4. Deriving Priorities for the Cultural Criterion Categories

	Extreme	Great	Significant	Moderate	Tad	Priorities	Idealized
Extreme	1	5	6	8	9	0.569	1
Great	1/5	1	4	5	7	0.234	0.411
Significant	1/6	1/4	1	3	5	0.107	0.188
Moderate	1/8	1/5	1/3	1	4	0.06	0.106
Tad	1/9	1/7	1/5	1/4	1	0.03	0.052

A score is computed for a city by multiplying the priority of the selected intensity times the priority of the criterion and summing for all the criteria, shown in the Total Score column in Table 5. The Priorities column is obtained by normalizing the Total Score column by dividing by the sum of the values in it. The selected intensities for each alternative, the ratings, are shown in Table below. The priorities corresponding to the ratings are shown in Table 6.

Table 5. Verbal Ratings of Cities under each Criterion

Alternatives	**Cultural**	**Family**	**Housing**	**Jobs**	**Trasport**	**Total Score**	**Priorities (Normal.)**
	0.195	0.394	0.056	0.325	0.03		
Pittsburgh	Signific.	<100 mi	Own>35%	Average	Manageable	**0.562**	**0.294**
Boston	Extreme	301-750 mi	Rent>35%	Above Avg.	Abundant	**0.512**	**0.267**
Bethesda	Great	101-300 mi	Rent<35%	Excellent	Considerable	**0.650**	**0.339**
Santa Fe	Signific.	>750 mi	Own>35%	Average	Negligible	**0.191**	**0.100**

Table 6. Priorities of Ratings of Cities under each Criterion

Alternatives	Cultural	Family	Housing	Jobs	Trasport	Total Score	Priorities (Normal.)
	0.195	0.394	0.056	0.325	0.030		
Pittsburgh	0.188	1	0.363	0.306	0.396	**0.562**	**0.294**
Boston	1	0.179	0.056	0.664	0.906	**0.512**	**0.267**
Bethesda	0.411	0.521	0.17	1	1	**0.650**	**0.339**
Santa Fe	0.188	0.079	0.363	0.306	0.120	**0.191**	**0.100**

9. Two Examples of Estimating Market Share

The Appendix of Chapter 2 shows all the comparison judgment matrices that go with the application. In Chapter 4 cluster comparisons, unweighted, weighted, and limit supermatrix are illustrated and all the priorities shown. The material in this section shows how well the network approach works in making decisions subject to a single control criterion: market share. Similarly chapter 2 deals with the prediction of the turn around date of the US economy (a single criterion of economic impacts) in 2001 and chapter 3 deals with a single financial control concern. It is also in Chapter 4 and nearly all the remaining chapters that we deal with the BOCR merits and their control criteria and with strategic criteria to effect their synthesis into an overall final outcome.

AIRLINE EXAMPLE (2005)

The first author's graduate students Nalin Gupta and Uwaifo Aromose did the following study of the market share of four US airlines. Nowhere did they use numerical data, but only their knowledge of the airlines and how good each is relative to the others on the factors mentioned below. Note that in four of the clusters there is an inner dependence loop which indicates that the elements in that cluster depend on each other with respect to market share. Figure 9 shows the model with the clusters and their inner and outer dependence connections.

They write: "We developed an Analytic Network Process model to find the business class market share of four airlines: British Airways, United Airlines, Continental Airlines and American Airlines. We grouped the criteria into four clusters which included service (leg room, food quality, digital entertainment and seat comfort), advertising (promotional , frequent flier program, frequency and global coverage), other (flight attendants hospitality, rapid rransit, connecting flights interval , reputation and price) and finally the alternatives (British Airways, United Airlines, Continental Airlines and American Airlines). "

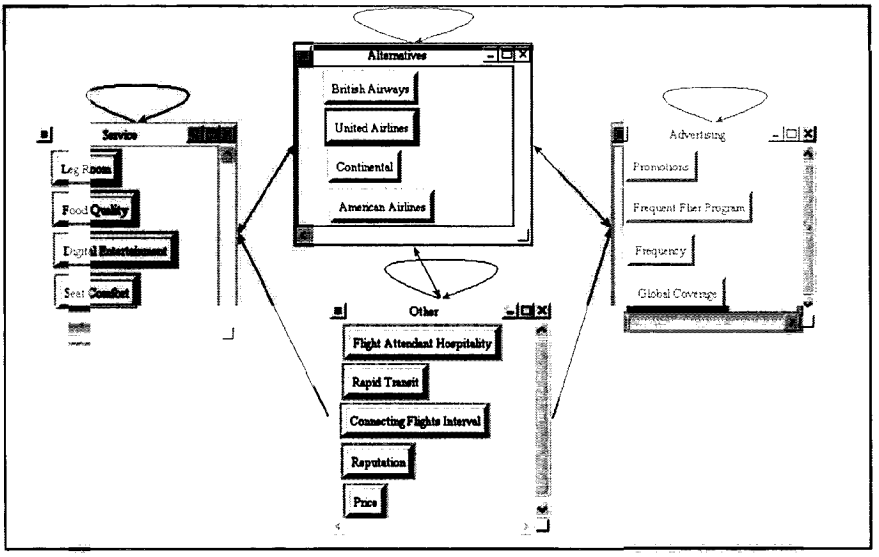

Figure 9. Airline Model from the ANP Super Decisions Software

The results from the ANP model and the actual market share are shown in Table 7 below.

Table 7. Actual and Predicted Relative Market Share of Airlines

	ANP Market Share	Actual Market Share
BA	38.0%	37%
AA	20.0%	19%
UA	20.9%	23%
CA	20.9%	21%

WINE EXAMPLE (2005)

Frank Bautti, also a student of the first author, did this example. He says, "I did my first model, a personal decision model, on types of wine grapes, so I will stick with the same theme and look at the market share of wine in U.S. food stores. There are basically three general categories for wine, red, white, and blush. I will give a prediction, build an ANP decision model to look at the results from it, and then compare those numbers to the 2004 wine market share statistics from the Wine Institute web site at www.wineinstitute.org under the 2004 sales link." The wine market-share model is shown in Figure 10 below.

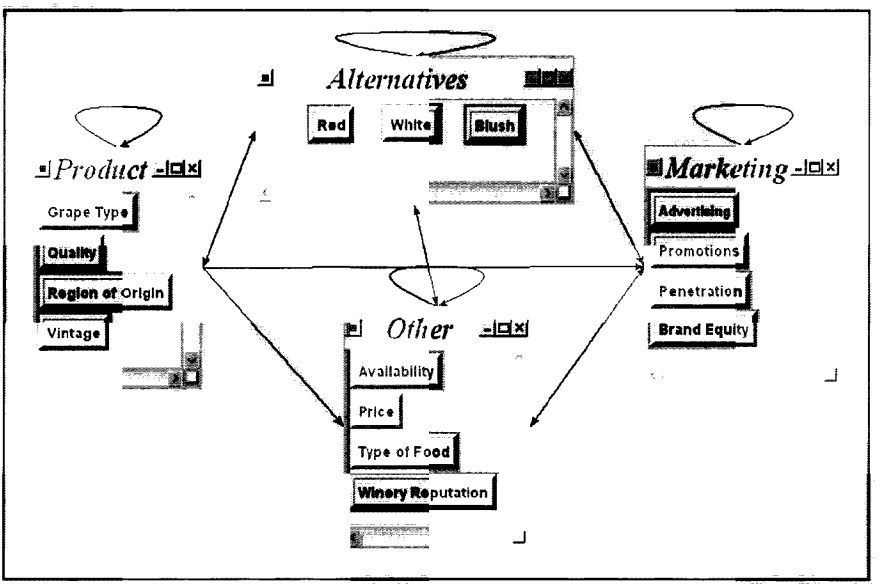

Figure 10. Airline Model from the ANP SuperDecisions Software

The relative market share as derived in the ANP model and the actual market share are shown in Table 8 below.

Table 8. Wine market share results

	*Actual	ANP Model
Red	40.5%	43.3%
White	40.4%	37.4%
Blush	19.1%	19.3%

* www.wineinstitute.org

10. GROUP DECISION MAKING

Here we consider two issues in group decision making. The first is how to aggregate individual judgments, and the second is how to construct a group choice from individual choices. The reciprocal property plays an important role in combining the judgments of several individuals to obtain a judgment for a group. Judgments must be combined so that the reciprocal of the synthesized judgments must be equal to the syntheses of the reciprocals of these judgments. It has been proved that the geometric mean is the unique way to do that. If the individuals are experts, they my not wish to combine their judgments but only their final outcome from a hierarchy. In that case one takes the geometric mean of the final outcomes. If the individuals have different priorities of importance, their judgments (final outcomes) are raised to the power of their priorities and then the geometric mean is formed.

How to Aggregate Individual Judgments

Let the function $f(x_1,...,x_n)$ for synthesizing the judgments given by n judges, satisfy the

(i) *Separability condition* (S): $f(x_1,...,x_n) = g(x_1)...g(x_n)$, for all $x_1,...,x_n$ in an interval P of positive numbers, where g is a function mapping P onto a proper interval J and is a continuous, associative and cancellative operation. [(S) means that the influences of the individual judgments can be separated as above.]

(ii) *Unanimity condition* (U): $f(x,...,x) = x$ for all x in P. [(U) means that if all individuals give the same judgment x, that judgment should also be the synthesized judgment.]

(iii) *Homogeneity condition* (H): $f(ux_1,...,ux_n) = uf(x_1,...,x_n)$ where $u > 0$ and x_k, ux_k $(k=1,2,...,n)$ are all in P. [For ratio judgments (H) means that if all individuals judge a ratio u times as large as another ratio, then the synthesized judgment should also be u times as large.]

(iv) *Power conditions* (P_p): $f(x_1^p,...,x_n^p) = f^p(x_1,...,x_n)$. [($P_2$) for example means that if the kth individual judges the length of a side of a square to be x_k, the synthesized judgment on the area of that square will be given by the square of the synthesized judgment on the length of its side.]

Special case ($R=P_{-1}$):

$$f(\frac{1}{x_1},...,\frac{1}{x_n}) = 1/f(x_1,...,x_n).$$

[(R) is of particular importance in ratio judgments. It means that the synthesized value of the reciprocal of the individual judgments should be the reciprocal of the synthesized value of the original judgments.]

Aczel and Saaty (Saaty, 2001) proved the following theorem:

Theorem *The general separable (S) synthesizing functions satisfying the unanimity (U) and homogeneity (H) conditions are the geometric mean and the root-mean-power. If moreover the reciprocal property (R) is assumed even for a single n-tuple* $(x_1,...,x_n)$ *of the judgments of n individuals, where not all* x_k *are equal, then only the geometric mean satisfies all the above conditions.*

In any rational consensus, those who know more should, accordingly, influence the consensus more strongly than those who are less knowledgeable. Some people are clearly wiser and more sensible in such matters than others, others may be more powerful and their opinions should be given appropriately greater weight. For such unequal importance of voters not all g's in (S) are the same function. In place of (S), the weighted separability property (WS) is now: $f(x_1,...,x_n) = g_1(x_1)...g_n(x_n)$ [(WS) implies that not all judging individuals have the same weight when the judgments are synthesized and the different

influences are reflected in the different functions $(g_1,...,g_n)$.]

In this situation, Aczel and Alsina (Saaty, 2001) proved the following theorem:

Theorem *The general weighted-separable (WS) synthesizing functions with the unanimity (U) and homogeneity (H) properties are the weighted geometric mean* $f(x_1,x_2,...,x_n)= = x_1^{q_1}x_2^{q_2}...x_n^{q_n}$ *and the weighted root-mean- powers* $f(x_1,x_2,...,x_n)=\sqrt[\gamma]{q_1x_1^{\gamma}+q_2x_2^{\gamma}...+q_nx_n^{\gamma}}$, *where* $q_1+...+q_n=1$, $q_k>0, k=1,...,n$, $\gamma>0$, *but otherwise* $q_1,...,q_n,\gamma$ *are arbitrary constants.*

If f also has the reciprocal property (R) and for a single set of entries $(x_1,...,x_n)$ of judgments of n individuals, where not all x_k are equal, then *only the weighted geometric mean* applies. We give the following theorem which is an explicit statement of the synthesis problem that follows from the previous results, and applies to the second and third cases of the deterministic approach:

Theorem *If* $x_1^{(i)},...,x_n^{(i)}$ *i=1, ..., m are rankings of n alternatives by m independent judges and if* a_i *is the importance of judge i developed from a hierarchy for evaluating the judges, and hence* $\sum_{i=1}^{m} a_i = 1$, *then* $\left(\prod_{i=1}^{m} x_1^{a_i}\right),...,\left(\prod_{i=1}^{m} x_n^{a_i}\right)$ *are the combined ranks of the alternatives for the m judges.*

The power or priority of judge i is simply a replication of the judgment of that judge (as if there are as many other judges as indicated by his/her power a_i), which implies multiplying his/her ratio by itself a_i times, and the result follows.

The first requires knowledge of the functions which the particular alternative performs and how well it compares with a standard or benchmark. The second requires comparison with the other alternatives to determine its importance.

On the Construction of Group Choice from Individual Choices

Given a group of individuals, a set of alternatives (with cardinality greater than 2), and individual ordinal preferences for the alternatives, Arrow proved with his Impossibility Theorem that it is impossible to derive a rational group choice (construct a social choice function that aggregates individual preferences) from ordinal preferences of the individuals that satisfy the following four conditions, i.e., at least one of them is violated:

Decisiveness: the aggregation procedure must generally produce a group

order.

Unanimity: if all individuals prefer alternative A to alternative B, then the aggregation procedure must produce a group order indicating that the group prefers A to B.

Independence of irrelevant alternatives: given two sets of alternatives which both include A and B, if all individuals prefer A to B in both sets, then the aggregation procedure must produce a group order indicating that the group, given any of the two sets of alternatives, prefers A to B.

No dictator: no single individual preferences determine the group order.

Using the absolute scale approach of the AHP, it can be shown that because now the individual preferences are cardinal rather than ordinal, it is *possible* to derive a rational group choice satisfying the above four conditions. It is possible because: a) Individual priority scales can always be derived from a set of pairwise cardinal preference judgments as long as they form at least a minimal spanning tree in the completely connected graph of the elements being compared; and b) The cardinal preference judgments associated with group choice belong to an absolute scale that represents the relative intensity of the group preferences (Saaty and Vargas, 2005).

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CHAPTER 2

FORECASTING THE RESURGENCE OF THE U.S. ECONOMY IN 2001: AN EXPERT JUDGMENT APPROACH

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1. INTRODUCTION

Building on work done in the early 1990s (Blair et al., 1992; Saaty and Vargas, 1994), this chapter illustrates use of the Analytic Network Process (ANP) (Saaty, 1990; Saaty, 2001; Saaty and Vargas, 1991) in April 2001 to produce a forecast of when the U.S. economy would recover from the slowdown it had been experiencing for several quarters, after almost a decade of unparalleled expansion. Using a conceptual framework grounded in modern macroeconomics, the exercise features the use of expert judgment in producing the forecast without assistance from conventional macroeconomic forecasting.

2. ON THE ROLE OF JUDGMENT IN ECONOMIC FORECASTING

Conventional approaches to macroeconomic forecasting tend to be constrained by the estimated values of parameters and intercept terms. These are imbedded in the multi-equation models that are typically employed to produce "first-cut" forecasts of relevant endogenous variables. Additionally, the values of a large number of "exogenous" variables (relating to the future course of monetary and fiscal policy, the value of exports, etc.) must be subjectively estimated on the basis of available evidence and consensus judgment. Initial forecasts produced by the raw models are then typically adjusted by "add" or "fudge" factors, most commonly in the form of shifts in the values of previously estimated intercept terms. This procedure is employed in order to produce forecasts that are consistent with recent values of key endogenous variables when it is evident that a shift of some kind has occurred in portions of the underlying model structure. Such exercises also provide ample opportunity for resetting the values of exogenous variables.

Studies of "ex ante" forecasts produced by the builders of major models using add factors suggest that these forecasts have been more accurate than the "ex post" forecasts produced by the models themselves, even when the same add factors were employed. Fair (1984) thus wrote:

> "In other words, the use of actual rather than guessed values of the exogenous variables decreased the accuracy of the forecasts.... This conclusion is consistent with the view that

> the add factors are (in a loose sense) more important than the model in determining the ex ante forecasts..."

As stated in earlier papers (Blair et al., 1992; Saaty and Vargas, 1994), all this suggests that macroeconomic model builders/forecasters are well aware of the limitations of their underlying models and the need to incorporate subjective judgments. However, these judgmental adjustments are necessarily non-systematic and ad hoc in nature. Here, we thus utilize an alternative, systematic approach – AHP – in order to remedy this deficiency. While we have not illustrated this alternative by adapting a formal macroeconomic forecasting model, the conceptual framework, as noted above, is grounded in modern macroeconomics. Our alternative approach, moreover, could also be readily employed to enrich forecasting exercises based on formal models (e.g. generating add factors more systematically and consistently; adjusting the values of exogenous variables). In this respect, the two forecasting approaches can be seen to converge quite compatibly.

3. THE SETTING: AN ECONOMIC SLOWDOWN AFTER YEARS OF EXPANSION

While in popular accounts it is conventional to view the U.S. economy as being in a recession if real Gross Domestic Product (GDP) has declined for two consecutive quarters, the National Bureau of Economic Research (NBER), utilizing a panel of experts, has, by consensus, been given the responsibility for dating the actual turning points in the U.S. economic cycle. That organization arrives at its assessments by utilizing a variety of economic indicators, including industrial production, employment/unemployment, income and shipments. The existence of a recession must meet various criteria relating to duration, depth and diffusion throughout the economy. In December of 1992, the NBER announced (Hershey, 1992)) that the trough of the last cycle had occurred in the first quarter of 1991. No economist would have predicted at the time that this trough would subsequently usher in a period of steady and substantial growth of national output, low inflation, rising productivity and progressively lower levels of unemployment, which would not falter until the third quarter of 2000. In that quarter, the growth rate of real GDP slipped to 2.2% from 5.6% in the previous quarter, and to 1.0% and 1.3% respectively in the fourth quarter of 2000 and the first quarter of 2001, as compared with an average rate of real quarterly GDP growth of 3.6% for the entire period (U.S. Dept. of Commerce, 2001). A U.S. Department of Commerce advance estimate of second quarter real GDP growth suggested an annual rate of 0.7%, with many economists expecting that a more complete report would indicate an actual contraction (Kulish, 2001). During this long expansionary period, civilian unemployment fell to levels last seen in the late 1960s, and which most economists had come to believe would not again be attained: steadily declining from an average of 7.3%/7.4% in 1991/1992 to a low of 3.9% in September and October of 2000, before beginning to rise in the ensuing months (Bureau of Labor Statistics, 2001).

Even in June 2001, the unemployment rate still stood at 4.5%, though expectations were widespread that this percentage would continue to increase for a number of months in the future. Fueled *ex post* by the steady growth in national output and, most significantly in the minds of many -- including Federal Reserve Chairman Alan Greenspan (e.g., Leonhardt, June, 2001; August, 2001) -- the long-awaited impact of the widespread use of computers and information technology, average rates of labor productivity growth also improved substantially during the expansion. Holding aside cyclical swings, non-farm business productivity had begun to lag during the 1980s and early 1990s but advanced significantly thereafter, averaging almost 2.5% per year from 1996 to 1999, and rising to an average of 4.3% in 2000, before slowing to a revised 0.1% in the first quarter of 2001, as the economic slowdown presumably began to exert its influence. Quite remarkably, a preliminary estimate of second quarter 2001 non-farm business productivity suggested a "healthy 2.5 percent" annual growth rate, attributable, apparently, to companies becoming "more efficient by dismissing employees or reducing the number of hours they worked, while sustaining virtually the same level of output" (Leonhardt, August, 2001). In any event, by the middle of June 2001, the NBER had released a statement in which it concluded there was "a possibility that a recession began recently" (Leonhardt, June, 2001.

From the beginning of 2001, the Federal Reserve had sharply reversed its previous year's monetary policy stance of raising interest rates in order to fend off inflation in what appeared to be a potentially overheating economy. No longer fearing inflationary pressure and expressing concern about the slowdown, the Federal Reserve lowered the benchmark Federal Funds rate six times between January and June 2000, for a total reduction in that rate of 2.75%, and also made it clear that it would not rule out further reductions in the future. Fiscal policy also made a late contribution in the form of the incorporation of an up to $600 tax rebate as part of the Economic Growth and Tax Relief Reconciliation Act of 2001, which President Bush had signed into law in June. Initially conceived exclusively as a program of longer-term tax relief, bi-partisan support for the package in part reflected the desire to resuscitate the lagging economy via fiscal stimulus. Rebate checks were slated to arrive in taxpayer mailboxes in the ensuing weeks.

The final version of the current chapter was prepared in August of 2001, and some of the information cited above was obviously not available when the authors convened to conduct a forecasting exercise on April 7, 2001, although the group had sufficient data at its disposal to conclude that the United States was experiencing an economic "slowdown." This is the term we will employ in this chapter, rather than "recession," although subsequent data may confirm that a recession actually did take hold. The purpose of the forecasting exercise was

to estimate when the next economic recovery would occur, in the form of a resurgence of stronger rates of output growth.

As additional context, we should compare the nature of the economic environment within which the forecasting exercises described in the previous paper (Blair et al., 1992; Saaty and Vargas, 1994) were conducted with the economic environment prevailing during the time of this most recent exercise. As stated in the previous paper, the authors' judgment in May 1992 was that the strength of the eventual recovery was likely to be quite weak when compared to previous expansions, owing chiefly to the "braking" influence of major structural changes then taking place in the domestic and global economies (specifically, such factors as the de-emphasis of production based on national defense and the increasing integration of world financial markets). Accordingly, a prominent place was assigned to the role of structural change in our previous forecasting framework. In our latest exercise, however, structural economic shifts were believed to have run their course and we thus adopted a more conventional macroeconomic forecasting framework, emphasizing "Aggregate Demand" and "Aggregate Supply" factors, as outlined in such widely adopted macroeconomics textbooks as Blanchard (Blanchard, 2000).

4. Application of ANP to the Macroeconomic Forecasting Problem

On the basis of the data available to us, our forecasting exercise employed the ANP to address the timing of the expected resurgence by seeking to answer the question "what is the most likely period in the future when the resurgence will occur?" By this term, we implicitly meant a resumption of something approaching the average growth rate of real GDP (serving as a surrogate measure of the growth of the overall U.S. economy) attained during the most recent, nearly decade-long, expansion. Like typical forecasters, we were not precise with regard to rates of growth in specific quarters, except to suggest the time period during which the resumption would occur.

4.1 Decomposition of the Problem as a Holarchy

Decomposing the problem hierarchically, the top level of the exercise consists of the primary factors believed by our group to represent the forces or major influences driving the economy: "Aggregate Demand" factors; " Aggregate Supply" factors; and "Geopolitical Context." Each of these primary categories was then decomposed into subfactors represented in the second level. Under Aggregate Demand, we identified consumer spending, exports, business capital investment, shifts in consumer and business investment confidence, fiscal policy, monetary policy, and expectations with regard to such questions as the future course of inflation, monetary policy and fiscal policy. (We make a distinction between consumer and business investment confidence shifts and the formation of expectations regarding future economic developments.)

Under Aggregate Supply, we identified labor costs (which, in turn, are driven by changes in such underlying factors as labor productivity and real wages), natural resource costs (e.g., energy costs), and expectations regarding such costs in the future. With regard to Geopolitical Context, we identified the likelihood of changes in major international political relationships and major international economic relationships as the principal subfactors. With regard to the subfactors under Aggregate Demand and Aggregate Supply, we recognized that they are, in some instances, interdependent. For example, a lowering of interest rates as the result of a monetary policy decision by the Federal Reserve should induce portfolio rebalancing throughout the economy. In turn, this should reduce the cost of capital to firms and stimulate investment. Simultaneously, it should reduce financial costs to households and increase their disposable incomes. Any resulting increase in disposable income stimulates consumption and, at the margin, has a positive impact on employment and GNP. However, all of this assumes that the linkages of the economy are in place and are well understood. This is what the conventional macroeconomic conceptual models are designed to convey.

The third level of the hierarchy consists of the alternate time periods in which the resurgence might occur as of April 7, 2001: within three months, within six months, within twelve months, and within twenty-four months. Because the primary factors and associated subfactors are time-dependent, their relative importance had to be established in terms of each of the four alternative time periods. Thus, instead of establishing a single goal as one does for a conventional hierarchy, we used the bottom level time periods to compare the two factors at the top. This entailed the creation of a feedback hierarchy known as a "holarchy" in which the priorities of the elements at the top level are determined in terms of the elements at the bottom level, thus creating an interactive loop. Figure 1 provides a schematic representation of the hierarchy we used to forecast the timing of the economic resurgence.

4.2 Pairwise Comparison

After decomposing the problem hierarchically, the next step in the process was to pairwise-compare the relative importances of the primary factors (Aggregate Demand, Aggregate Supply, and the Geopolitical Context) as they influence (1) the timing of the economic resurgence; (2) the relative importance of each of the subfactors as drivers of the associated primary factor in the next level of the hierarchy; and (3) the relative importance of each of the subfactors under each primary factor as it influences the timing of the economic resurgence. These comparisons were carried out using the AHP's nine point scale.

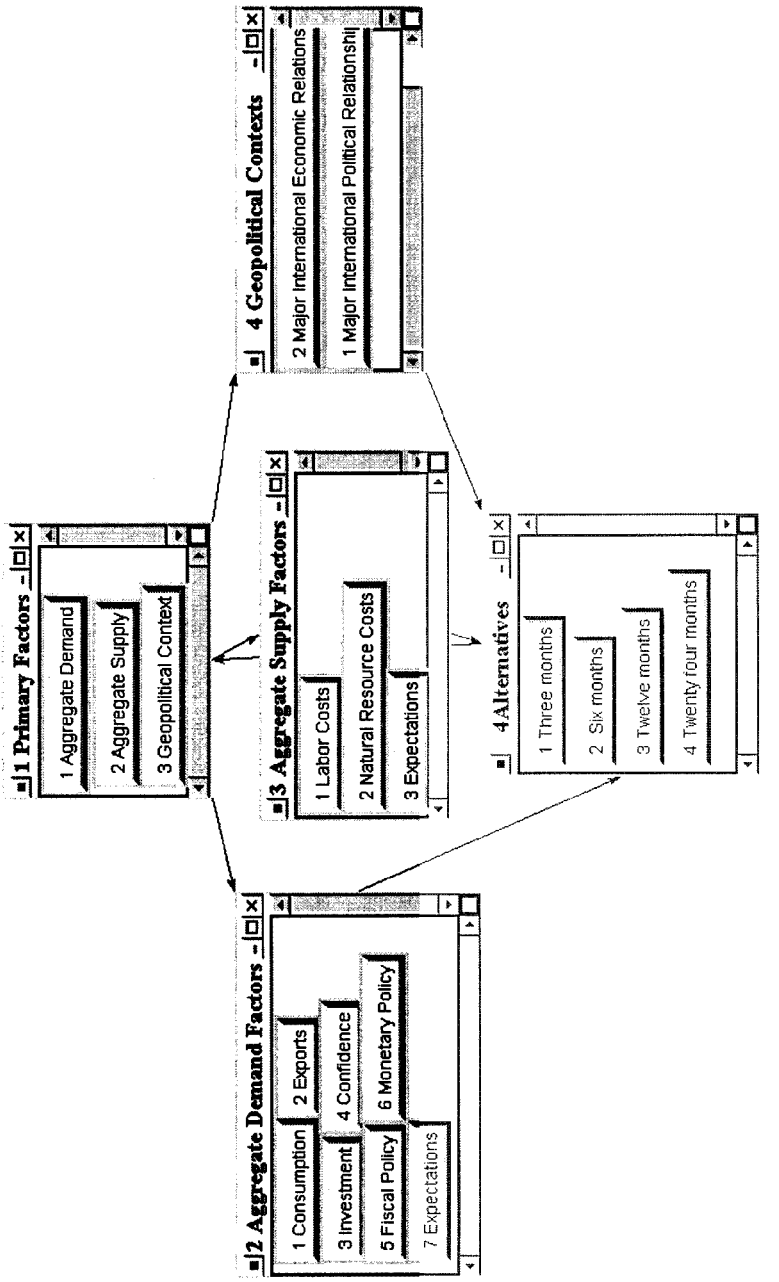

Figure 1. Overall View of the "2001" Model

The judgments with regard to identification of factors, as well as the comparisons of relative impact and strength of factors, were conducted by the authors, who assumed the role of representative "experts". Obviously, the outcomes are strongly dependent on the quality of those judgments. As noted, the exercise was conducted on April 7, 2001.

Nineteen sets of judgment matrices were generated in this exercise. Tables 3 through 21 in the Appendix present the 19 judgment matrices and their resulting priorities for this forecasting exercise. A whole number in a matrix means the element listed at the left is preferred to the element listed at the top. A fraction means the element listed at the top is preferred. Note that the bottom left triangular portion of each matrix below the main diagonal is omitted since the corresponding entries there are the reciprocals of their transposes shown above the main diagonal.

Table 19 in the Appendix provides an easily grasped illustration of the use of this scale to represent the judgments. With regard to the relative importances of the three primary factors for promoting an economic resurgence within a six-month time period, the table reveals that Aggregate Demand factors were considered to be "very strongly more important" (seven times as important) than Aggregate Supply factors, and "extremely more important" (nine times as important) than Geopolitical factors. Accordingly, the numbers 7 and 9 were inserted in the columns under Aggregate Supply and Geopolitical, respectively, to illustrate the comparisons of Aggregate Demand with these factors.

A perusal of the table reveals the following sets of judgments:

1. The monetary policy, confidence and expectational subfactors were assigned relative weights totaling almost 75% of the Aggregate Demand primary factor -- with monetary policy the highest at 35% -- in regard to promoting economic resurgence (i.e., by directly impacting on consumer spending and business capital investment).

2. With regard to the three and six-month forecasting periods, Aggregate Demand factors were judged to dominate Aggregate Supply and Geopolitical factors (79% in each period); for the longer 12- and 24-month time horizons, Aggregate Demand and Aggregate Supply factors were judged to be of equal weight (45% in each period).

3. Of the Aggregate Demand subfactors, confidence, monetary policy and expectations were judged to be most influential in the three- and six-month forecasting horizons, whereas more fundamental aspects of consumer spending and business capital investment, together with exports, began to assume greater prominence, along with the Aggregate Supply subfactors, in the 12- and 24-month time periods.

Each judgment matrix has an associated priority vector or vector of weights. (These are the numbers that appear in the supermatrix, Table 1, in the Appendix.) The limit supermatrix (Table 2 in the Appendix) is the result of raising the supermatrix to powers until it converges. In this case, the powers of the supermatrix perform a cycle, and for the overall limit, the sum of the various limiting cycle phases is taken to obtain the outcome. This is the final supermatrix of the results. The resulting final priorities for the alternative time periods are obtained from the last four rows of any column in Table 2 by normalizing the four numbers: 0.1019, 0.0686, 0.0606, and 0.1022. The resulting final priorities for the time periods are: three months, 0.3058; six months, 0.2058; twelve months, 0.1818; and twenty-four months, 0.3066.

5. PRODUCING THE FORECAST OF THE RECOVERY

To obtain our forecast, we subsequently multiplied each priority by the midpoint of its corresponding time interval and added the results (as one does when evaluating expected values):

Time Period	Midpoint of Time Period (in months from 0)	Priority of Time Period		Midpoint x Priority
3 – months	0 + (3 – 0)/2 = 1.5	0.3058		0.4587
6 – months	3 + (6 – 3)/2 = 4.5	0.2058		0.9262
12 – months	6 + (12 – 6)/2 = 9.0	0.1818		1.6363
24 – months	12 + (24 – 12)/2 = 18.0	0.3066		5.5180
			TOTAL	**8.5393**

We interpreted this to mean that the recovery would occur 8.54 months from the time of the forecasting exercise on April 7, 2001, or around mid to late December, 2001; that is to say, toward the end of the fourth quarter of 2001. Interestingly, as this chapter was drafted in July 2001, a number of private and official forecasters were also making similar projections (i.e., a recovery in the fourth quarter of 2001, or the first quarter of 2002). [1]

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[1] An economist colleague, Professor Iwan Azis of Cornell University, has suggested that instead of using the midpoints of the time intervals, which is more the practice in the physical sciences, that the endpoints should be used. His idea is that the pairwise comparisons should be formulated in terms of what is likely to happen by the end of one period (e.g. three months) versus the end of another period (such as twelve months) rather than using the mid-points of these periods. As of the starting date of a forecasting exercise, it is the end points of the various time periods which are of interest rather than the mid-points or averages for each period. In that case, the resurgence would be computed as follows: 3 x 0.30581 + 6 x 0.20583 + 12 x 0.18181 + 24 x 0.30656 = 11.69 (months from April 7, 2001), or approximately April of 2002 (i.e., early in the

6. CONCLUSION

This chapter has again demonstrated how the Analytic Network Process can serve as an additional tool for macroeconomic forecasts. In the current instance, we have used the interesting case of the U.S. economy in early 2001, which had begun to experience a slowdown during the latter part of the year 2000 after more than nine years of steady expansion, in order to forecast the time period prior to its recovery. As noted earlier, this approach could be easily adapted for use in forecasts employing formal macroeconometric models (e.g. to make judgments with respect to shifts in intercepts and changes in the values of exogenous variables). By way of validating our forecast, here is what the Wall Street Journal July 18, 2003 wrote about the subject more than two years after: "The National Bureau of Economic Research said the U.S. economic recession that began in March 2001 ended **eight months later**, not long after the Sept. 11 terrorist attacks. Most economists concluded more than a year ago that the recession ended in late 2001. But yesterday's declaration by the NBER-a private, nonprofit economic research group that is considered the official arbiter of recession timing-came after a lengthy internal debate over whether there can be an economic recovery if the labor market continues to contract. The bureau's answer: a decisive yes. "

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averages for each period. In that case, the resurgence would be computed as follows: 3 x 0.30581 + 6 x 0.20583 + 12 x 0.18181 + 24 x 0.30656 = 11.69 (months from April 7, 2001), or approximately April of 2002 (i.e., early in the second quarter of 2002). This compares to our result of mid- to late December, 2001 (i.e., late in the fourth quarter of 2001). Given the inherent imprecision in producing economic forecasts, this difference is clearly within the margin of error in one direction or the other. The actual timing of the resurgence will not be known until at least several quarters thereafter.

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APPENDIX

Table 1. Supermatrix. It contains the weights or priorities for the pairwise comparison matrices

	1 Primary Factors			2 Aggregate Demand Factors							3 Aggregate Supply Factors			4 Geopolitical Contexts		4Alternatives			
	1 Aggregate Demand	2 Aggregate Supply	3 Geo-political Context	1 Consumption	2 Exports	3 Investment	4 Confi-dence	5 Fiscal Policy	6 Mone-tary Policy	7 Expecta-tions	1 Labor Costs	2 Natural Resource Costs	3 Expectations	1 Major International Political Relations	2 Major International Economic Relations	1 Three Months	2 Six Months	3 Twelve Months	4 Twenty Four Months
1 Aggregate Demand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.79	0.45	0.45
2 Aggregate Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.45	0.45
3 Geopolitical Context	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.09	0.09
1 Consumption	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 Exports	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 Investment	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 Confidence	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 Fiscal Policy	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 Monetary Policy	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 Expectations	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 Labor Costs	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 Natural Resource Costs	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 Expectations	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 Major International Political Relations	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 Major International Economic Relations	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 Three months	0.00	0.00	0.00	0.04	0.08	0.08	0.52	0.10	0.61	0.46	0.08	0.06	0.56	0.06	0.06	0.00	0.00	0.00	0.00
2 Six	0.00	0.00	0.00	0.11	0.08	0.08	0.30	0.09	0.26	0.37	0.15	0.12	0.29	0.12	0.12	0.00	0.00	0.00	0.00
3 Twelve	0.00	0.00	0.00	0.31	0.42	0.31	0.12	0.38	0.04	0.10	0.23	0.26	0.08	0.26	0.26	0.00	0.00	0.00	0.00
4 Twenty four	0.00	0.00	0.00	0.53	0.42	0.54	0.05	0.43	0.09	0.08	0.53	0.57	0.07	0.57	0.57	0.00	0.00	0.00	0.00

Table 2. The limit supermatrix

	1 Primary Factors			2 Aggregate Demand Factors							3 Aggregate Supply Factors			4 Geopolitical Contexts		4Alternatives			
	1 Aggregate Demand	2 Aggregate Supply	3 Geo-Political Context	1 Consump-tion	2 Exports	3 Invest-ment	4 Confi-dence	5 Fiscal Policy	6 Monetary Policy	7 Expecta-tions	1 Labor Costs	2 Natural Resource Costs	3 Expecta-tions	1 Major International Political Relations	2 Major International Economic Relations	1 Three Months	2 Six Months	3 Twelve Months	4 Twenty Four Months
1 Aggregate Demand	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
2 Aggregate Supply	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
3 Geopolitical Context	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1 Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2 Exports	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 Investment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4 Confidence	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5 Fiscal Policy	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6 Monetary Policy	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
7 Expectations	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1 Labor Costs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2 Natural Resource Costs	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
3 Expectations	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1 Major International Political Relations	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2 Major International Economic Relations	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1 Three months	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
2 Six	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
3 Twelve	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
4 Twenty four	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 3. The Judgments for Aggregate Demand Factors with respect to the Aggregate Demand Node

	1Consumption	2Exports	3Investment	4Confidence	5Fiscal Policy	6Monetary Policy	7Expectations	Weights
1Consumption	1	7	5	1/5	1/2	1/5	1	.0979
2Exports		1	1/5	1/5	1/5	1/7	1/7	.0209
3Investment			1	1/5	1/3	1/5	1	.0564
4Confidence				1	5	1	1/3	.2220
5Fiscal Policy					1	1/5	1/3	.0835
6Monetary Policy						1	1/5	.3540
7Expectations							1	.1653

Table 4. The Judgments for the Aggregate Supply Factors with respect to the Aggregate-Supply-Node

	Labor Costs	Natural Resources	Expectations	Weights
Labor Costs	1	1/7	1	0.1194
Natural Resources		1	5	0.7470
Expectations			1	0.1336

Table 5. The Judgments for the Geopolitical Context Factors with respect to the Geopolitical-Context-Node

	International Political Relations	International Economic Relations	Weights
International Political Relations	1	1/2	0.6667
International Economic Relations		1	0.3333

Table 6. The Judgments for the Alternatives with respect to Consumption

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1/5	1/7	1/7	0.0426
6 Months		1	1/5	1/5	0.1135
12 Months			1	1/3	0.3101
24 Months				1	0.5338

Table 7. The Judgments for the Alternatives with respect to Exports

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1	1/5	1/5	0.0833
6 Months		1	1/5	1/5	0.0833
12 Months			1	1	0.4167
24 Months				1	0.4167

Table 8. The Judgments for the Alternatives with respect to Investment

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1	1/5	1/5	0.0783
6 Months		1	1/5	1/5	0.0783
12 Months			1	1/3	0.3051
24 Months				1	0.5383

Table 9. The Judgments for the Alternatives with respect to Confidence

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	3	5	5	0.5168
6 Months		1	5	5	0.3047
12 Months			1	5	0.1244
24 Months				1	0.0541

Table 10. The Judgments for the Alternatives with respect to Fiscal Policy

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1	1/3	1/5	0.0990
6 Months		1	1/5	1/5	0.0864
12 Months			1	1	0.3827
24 Months				1	0.4319

Table 11. The Judgments for the Alternatives with respect to Monetary Policy

	3 Months	6 Months	12 Months	24 Months	Weights.
3 Months	1	5	7	7	0.6052
6 Months		1	5	7	0.2616
12 Months			1	1/5	0.0424
24 Months				1	0.0908

Table 12. The Judgments for the Alternatives with respect to Expectations

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1	5	7	0.4562
6 Months		1	3	5	0.3707
12 Months			1	1	0.0958
24 Months				1	0.0772

Table 13. The Judgments for the Alternatives with respect to Labor Costs

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1	1/5	1/7	0.0842
6 Months		1	1	1/3	0.1515
12 Months			1	1/3	0.2307
24 Months				1	0.5336

Table 14. The Judgments for the Alternatives with respect to Natural Resources

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1/3	1/5	1/7	0.0553
6 Months		1	1/3	1/5	0.1175
12 Months			1	1/3	0.2622
24 Months				1	0.5650

Table 15. The Judgments for the Alternatives with respect to Expectations

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	3	5	7	0.5602
6 Months		1	4	6	0.2921
12 Months			1	1	0.0807
24 Months				1	0.0671

Table 16. The Judgments for the Alternatives with respect to Major International Political Relations

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1/3	1/5	1/7	0.0553
6 Months		1	1/3	1/5	0.1175
12 Months			1	1/3	0.2622
24 Months				1	0.5650

Table 17. The Judgments for the Alternatives with respect to Major International Economic Relations

	3 Months	6 Months	12 Months	24 Months	Weights
3 Months	1	1/3	1/5	1/7	0.0553
6 Months		1	1/3	1/5	0.1175
12 Months			1	1/3	0.2622
24 Months				1	0.5650

Table 18. The Judgments for the Primary Factors with respect to the 3 Month Time Period

	Aggregate Demand	Aggregate Supply	Geopolitical	Weights
Aggregate Demand	1	7	9	0.7854
Aggregate Supply		1	3	0.1488
Geopolitical			1	0.0658

Table 19. The Judgments for the Primary Factors with respect to the 6 Month Time Period

	Aggregate Demand	Aggregate Supply	Geopolitical	Weights
Aggregate Demand	1	7	9	0.7854
Aggregate Supply		1	3	0.1488
Geopolitical			1	0.0658

Table 20. The Judgments for the Primary Factors with respect to the 12 Month Time Period

	Aggregate Demand	Aggregate Supply	Geopolitical	Weights
Aggregate Demand	1	1	5	0.4545
Aggregate Supply		1	5	0.4545
Geopolitical			1	0.0909

Table 21. The Judgments for the Primary Factors with respect to the 24 Month Time Period

	Aggregate Demand	Aggregate Supply	Geopolitical	Weights
Aggregate Demand	1	1	5	0.4545
Aggregate Supply		1	5	0.4545
Geopolitical			1	0.0909

CHAPTER 3

AN ANALYTIC NETWORK PROCESS MODEL FOR FINANCIAL-CRISIS FORECASTING

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1. INTRODUCTION

William Stanley Jevons (1835-1882) was a highly respected and influential economist and statistician of his time. Jevons argued in his book, Investigations in Currency and Finance, the economy underwent a series of "commercial crises," which he traced back to the eighteenth century. Jevons' view of the trade or business cycle as a sequence of crises was embraced broadly throughout the economics profession until the 1920s. Then as more economic and financial data were compiled and newer statistical techniques were crafted to analyze them, Wesley Mitchell's "statistical cycles" replaced the event-driven concept of the business cycle. Statistical time-series cycles continue to underlie modern business cycle research. Today, cyclical composite index models, probit models, hidden Markov models (HMM) and threshold autoregressive (TAR) models are some typical methodologies used to forecast turning points in statistical cycles.

However, over the last ten years, the literature on financial crises rediscovered the traditional Jevons view of the cycle, where a turning point is triggered by some economic and/or political event. Financial crises are sudden events that may and often do occur after a growth cycle slowdown begins or classical business cycle recession ensues. Crises are predicated on some development, such as a collapse of a financial or non-financial institution or the recognition of a major imbalance in the financial sector, such as heavy debt holdings or too much dependence on foreign capital.

In modern crisis theory of the business cycle, three types of financial crises are identified: fiscal, banking and currency (Sachs, 1998). A fiscal crisis occurs when a government cannot roll over foreign debt and/or attract new loans. A currency crisis occurs when investors shift demand to foreign-denominated assets and away from domestic assets. A banking crisis occurs when a bank cannot attract enough new deposits to meet sudden withdrawal of reserves. Each of these crises can exist independently or in conjunction with one or more other crisis.

Statistical data needed to track and to forecast a potential financial-crisis point can be somewhat illusive from country to country. Data limitations exist especially in some emerging market economies that have undergone major

structural change. In those countries, historical data are no longer consistent with the present institutions and, as such, are insufficient to signal a financial crisis before it occurs. Even when data exist, judgmental variables play a role in statistical models, as witnessed by the "freedom from corruption" qualitative variable in the probit model by Radelet and Sachs (1998).

For these reasons, we propose a flexible and comprehensive framework to simultaneously model and forecast the three types of financial crisis using an Analytic Hierarchy Process (AHP) with feedback, which is known as the Analytic Network Process (ANP) as developed and implemented by Saaty (1996). The Analytic Network Process also provides a structure that potentially can reduce judgmental forecast error through improved "reliability of information processing."

The modeling application in this chapter extends the ANP recession forecasting model by Blair et al. (2002) to capture key economic concepts specified in the financial-crisis econometric model by Kaminsky and Reinhart (1999), the contagion econometric model by Lowell et al. (1998), as well as the studies by Aziz et al. (2000), Burns (1969), Glick and Moreno (1999), IMF (1998), Kindleberger (1996) and Wolfson (1994). Our ANP financial crisis model's determinants are directly specified using quantitative and qualitative variables and empirically tested using an "expert system" approach instead of a true "expert opinion" approach – as the Blair study did – to allow for an historical back test.

2. THE ANP FINANCIAL CRISIS MODEL STRUCTURE

The Analytic Network Process provides the mathematical framework for our model to forecast a financial-crisis probability using heuristics. Conceptually, the financial-crisis model can be described as a system of n components (which may be part of a cluster of components) that forms a network where every component (Cn) can interact or have an influence on itself or some or all of the other components of the system. The network, N ={C, L}, where C = {Ca, Cb, Cc, ..., Cn} and L = {{Ca, Ca},{Ca, Cb},{Ca, Cc}, ...,{Cn, Cn}} such that L represents the set of pairwise linkage within or between components of the network. The ANP-based crisis-forecasting model provides a formal scheme for mapping the component evaluations to an aggregate judgmental probability of a crisis (Saaty, 1990, 1994, 1996). This multi-criteria decision-making/forecasting model derives priorities or weights for each of the "n" criteria or components, Cn, of the model based on their judged (by the forecaster or a consensus of forecaster opinion) relative importance to the overall goal – which in this application is the likelihood that it will contribute to a financial crisis in a given period of time for a given forecast horizon. Not surprisingly, this process shares a common conceptual foundation with the derivation of component contributions from regression-based, time-series and/or cyclical-indicator composite index methodologies (Zarnowitz & Boschan,

1975). However, the derivation of the ANP priority weights, which use pairwise assessment based on statistical or judgmental relevance, is quite different from those more traditional methods (Frei & Harker, 1999; Niemira, 2001).

The Analytic Network Process framework is based on the following basic definitions and axioms: (a) A priority or weight, which is an absolute number, belongs to the closed interval [0,1] and is a measure of relative dominance; (b) A reciprocal condition exists that posits the ratio comparison between components is possible such that an evaluation of the pairwise couplet (CA,CB) equals 1/(CB,CA); (c) Homogeneity exists, which is the motivation for the Saaty 1-9 evaluation scale whereby the upper limit of 9 on that scale is due to the requirement of homogeneity to maintain the stability of the eigenvector to perturbation from consistency, and also to the requirement that only a small number of elements should be compared (an eigenvector with a small number of components considered.); and (d) A dependence condition is assumed that the system can be decomposed into component parts. Both the scale and the number of elements compared can be extended indefinitely. This is done by creating clusters with a small number of homogeneous elements in each and using a pivot element from cluster to the next (the largest in one is the smallest in the other) and applying the scale 1-9 to compare the elements in each, dividing by the priority of the pivot in the second cluster and multiplying the resulting priorities by the priority of the pivot in the first cluster and then combining the two clusters.

Moreover, the Analytic Network Process extends the AHP method to incorporate component dependence and feedback by using a supermatrix approach (Saaty, 1996). A supermatrix, W, is a complete system matrix of components, {Ca, Cb, Cc, ..., Cn}, and their linkages or system weights, Wij, where Ci = {ei1, ei2, ..., ein} is the sub-component elements of the criterion component "i." ANP allows interaction and feedback within clusters, Ci, which is known as inner dependence, and between clusters, which is known as outer dependence. To make this more concrete, if there is no linkage between, say component Cb and Cc, then Wbc would be zero. However, if there is some relationship, then the entry would be non-zero, suggesting an outer dependence. An inner dependence would exist if there is a linkage within the components of a cluster, {ei1, ei2, ..., ein}.

Finally, the actual elements making up the columns (Wij) of the supermatrix are the eigenvector solutions within the clusters (such that each column sums to one). This supermatrix represents the impact of all model elements relative to the complete element set. The final priority weights — which account for component (element) interactions — are derived by multiplying the supermatrix by itself until the columns stabilize, which occurs when the supermatrix entries become identical across each row and this is known as the limiting matrix. The final priority weights are extracted from this limiting matrix. In essence, this solution algorithm derives weights that account

for component interaction, which is a clear benefit of the dynamic ANP model over static models.

3. Building the ANP Financial Crisis Model

Our objective is to demonstrate that an ANP model structure incorporating a majority of variables from prior studies can be used to predict the likelihood that an economy would be in "financial crisis," of any form, within six months. Explicitly, the model must account for banking, currency and fiscal crises as well as contagion effects on the domestic economy from other countries experiencing one of more of those crises. Moreover, it would be useful to include a conceptual range of "all possible" indicators of financial crisis into this model, even if some rarely occur and might not show up as statistically significant in econometric models. One of the advantages of the ANP framework is that it is not constrained by some statistical problems, such as multicollinearity, which might be encountered in econometric modeling of the same process. In this way, the ANP model shares a common conceptual foundation with traditional composite indicator methods, which also attempt to select indicators across a wide spectrum of economic processes. Diversification of the criteria used to trigger a forecast decision is important, but one should not give too much weight to trivial indicators, even if the variable is included for completeness.

Arguably, the greatest advantage of the ANP model is that it can handle data limitations and intangibles (or qualitative variables – such as political or war risk) based on individual or collective judgment of the situation. As such, the measurement of intangibles is the main concern of the mathematics of the AHP/ANP approach. Often even if there are no recent statistical data or no time series at all for such intangibles, there may be a qualitative sense of the importance of the factor (that might be gleaned through news reports, for example), which can be accounted for and incorporated into the ANP forecasting model.

Our model, which is dubbed the imbalance-crisis-turning-point model, incorporates the following features: (1) contagion effects, (2) fiscal crises, (3) banking crises, (4) currency crises, (5) the role of real-sector changes, (6) monetary policy, (7) fiscal or tax policy and (8) external shocks, which include oil prices, food prices and technological or productivity changes (this block also might include other exogenous influences, including legal restrictions on capital flows, political instability, social unrest, etc.). The imbalance-crisis turning point ANP model is specified by clusters of criteria, their elements and the connection between them and judgmental evaluations are made with a forecast horizon of up to six months.

The control cluster, in our model, is diagramed in Figure 1. The arrows indicate direction of causal impact with the looped arrow indicating feedback

effects. For example, in the exogenous-shocks block, it is assumed that an impact from oil prices will impact productivity shocks. The domestic imbalance criteria incorporate typical theoretical concepts and empirical evidence, but can be customized for a specific country's economy. As we have modeled the process, the domestic imbalance block includes evaluations of capacity utilization rates (too low or too high could be problems), the ratio of cashflow-to-investment (ability to afford the investment), the consumer debt burden (an over-leveraged consumer could pose problems for the economy), foreign debt reliance (capital or current account deficit problem), labor shortages (implications for wages or immigration policy) and profit margins (ability to sustain business). The policy actions block includes evaluations of tax policy and monetary policy. The sources-of-financial-crisis block includes evaluations on banking, currency, fiscal deficits and crisis contagion. The exogenous block includes evaluations on oil price shocks, food price shocks and productivity shocks (which encompass numerous factors from strikes to technological impacts). Finally, the financial crisis chance block includes two elements – crisis or no crisis.

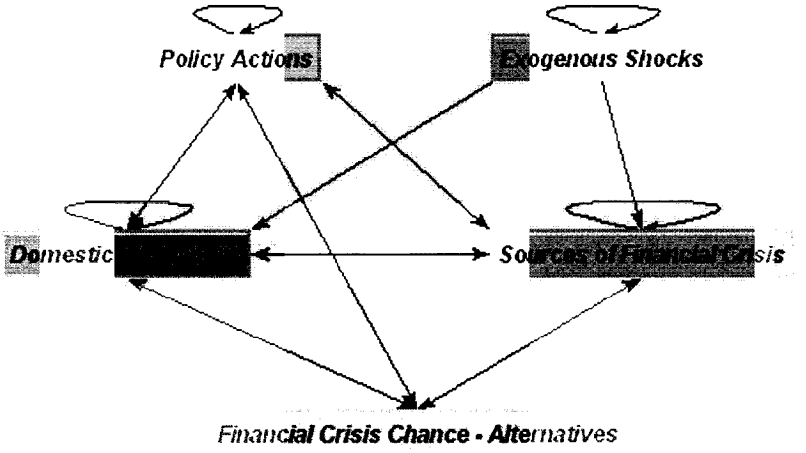

Figure 1. Overview: The ANP-Network Financial Crisis Model's Control Hierarchy

Although these elements are generic enough to cover most economies, there would be a need to customize the sub-criteria for a specific type of economy. For example, the consumer debt burden sub-criterion, which is a component of domestic imbalance in some developed countries, would not apply to every economy since some local customs or banking system infrastructures would not result in heavy consumer borrowing. Similarly, labor shortages may be a problem in developed countries, but not in emerging markets.

Once the characteristics of the model have been specified, then the forecaster must provide judgments on the relative importance of those various factors in the model as they relate to the system's alternatives (in this case,

financial crisis or not). The process to solve the ANP forecasting model is as follows:

Step 1: Determine the Main Cluster Weights. The main or control cluster weights for {Ca, Cb, Cc, ..., Cn} are determined based on: (1) whether there is feedback in the cluster (if not, the matrix entry is zero), and (2) the intensity of the relationship between the cluster and other clusters using the nine-point scale (see Table 1). Instead of assigning two numbers wi and wj and forming the ratio wi/wj, we assign a single number drawn from the fundamental 1-9 scale of absolute numbers to represent the ratio (wi/wj)/1. It is a nearest integer approximation to the ratio wi/wj. The derived scale will reveal what the wi and wj are. This is a central fact about the relative measurement approach used within ANP and the need for a fundamental scale. However, it should be noted that the 1-9 evaluation scale, in principle, has an unlimited range given the homogeneity and clustering that are used to extend the fundamental scale gradually from cluster to adjacent cluster, eventually enlarging the scale from 1-9 to $1\text{-}\infty$.

To illustrate the development of the main cluster weights in our model, first observe that the exogenous-shock and financial-crisis-risk clusters do not include feedback (Figure 1). Consequently, the entries for both clusters in the control matrix are zero. On the other hand, the policy actions, imbalances, and sources of financial crisis clusters are modeled with feedback given that those actions, events or activities can spiral upon themselves. This means a full forecast period effect must be assessed/forecasted akin to using the "dynamic multiplier" in stochastic modeling and cutting off the cumulative effect at the end of the forecast horizon. The crisis model's forecast horizon is specified as six months.

The pairwise comparisons and normalized weights for the five components of the main cluster are derived as paired comparisons of intensities, based on the 9-point scale. The development of the main-cluster priority weights is shown in Table 2 for a hypothetical developed economy.

With respect to domestic imbalances, for example, a pairwise comparison of the sources-of-crisis criterion compared with the financial-crisis chance might be assigned a score in the control matrix of "8", which would mean that the sources-of-crisis component has a very high likelihood of impacting domestic imbalances relative to the financial-crisis chance. These ratings – demonstrated here as judgmental scores – incorporate "existing knowledge" about the economic landscape from various informational sources. Each score encompasses two aspects of the forecasting process into one evaluation measure: (a) the significance of the cluster or economic process relative to the overall stated objective, and (b) the current importance of that factor. Although the former aspect may be relatively invariant over time, the latter evaluation criterion will clearly change.

Table 1. The Fundamental Scale: Numerical Ratings Associated With Pairwise Comparisons

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption

Table 2. Formulating the Control Matrix

With Respect to DOMESTIC IMBALANCE					
	Domestic Imbalances	Financial Crisis Chance	Policy Actions	Source of Crisis	Weights
Domestic Imbalances	1	7	3	1	0.426
Financial Crisis Chance	1/7	1	1/2	1/8	0.051
Policy Actions	1/3	2	1	1	0.180
Source of Crisis	1	8	1	1	0.344
Inconsistency Index = 0.061 (Desirable value to be less than 0.10)					

With Respect to Financial Crisis Chance				
	Domestic Imbalances	Policy Actions	Source of Crisis	Weights
Domestic Imbalances	1	1	1	0.333
Policy Actions	1	1	1	0.333
Source of Crisis	1	1	1	0.333
Inconsistency Index = 0.000 (Desirable value to be less than 0.10)				

With Respect to Policy Actions					
	Domestic Imbalances	Financial Crisis Chance	Policy Actions	Source of Crisis	Weights
Domestic Imbalances	1	1	3	3	0.377
Financial Crisis Chance	1	1	4	2	0.367
Policy Actions	1/3	1/4	1	2	0.139
Source of Crisis	1/3	1/2	1/2	1	0.117
Inconsistency Index = 0.051 (Desirable value to be less than 0.10)					

With Respect to Policy Actions					
	Domestic Imbalances	Financial Crisis Chance	Policy Actions	Source of Crisis	Weights
Domestic Imbalances	1	2	2	2	0.400
Financial Crisis Chance	1/2	1	1	1	0.200
Policy Actions	1/2	1	1	1	0.200
Source of Crisis	1/2	1	1	1	0.200
Inconsistency Index = 0.000 (Desirable value to be less than 0.10)					

With Respect to Exogenous Shocks				
	Domestic Imbalances	Policy Actions	Source of Crisis	Weights
Domestic Imbalances	1	1	1	0.333
Policy Actions	1	1	1	0.333
Source of Crisis	1	1	1	0.333
Inconsistency Index = 0.000 (Desirable value to be less than 0.10)				

Control Matrix Node	Domestic Imbalances	Financial Crisis Chance	Policy Actions	Sources of Crisis	Exogenous Shocks
Domestic Imbalances	0.426	0.333	0.377	0.400	0.333
Financial Crisis Chance	0.051	0.000	0.367	0.200	0.000
Policy Actions	0.180	0.333	0.139	0.200	0.000
Sources of Crisis	0.344	0.333	0.117	0.200	0.333
Exogenous Shocks	0.051	0.000	0.000	0.000	0.333

Step 2: Determine the Pairwise Comparisons for the Model Elements. The model weights within each cluster, {ei1, ei2, ..., ein}, also are derived using the standard application of AHP. Again, pairwise comparisons are used to establish the element relationships within each cluster; the principal right eigenvector of observable pairwise-comparison matrix, A, from the system of homogeneous linear equations, Aw = nw, provides the element weights at this level, which will be used in the supermatrix. As an aside, the formulation of this problem shows that the scale for the weights, in the original units, can be recovered from the matrix of ratios by solving the problem Aw = nw or (A - nI)w = 0, which provides further assurance that the weights are mathematically related to the unobserved vector, w – that is with judicious pairwise judgment the derived weights should closely mirror the actual weights if they are available for checking.

To demonstrate the process, consider an evaluation of paired comparison within the domestic imbalances block of the ANP model. The matrix of paired comparisons in this example might look as demonstrated in Table 3 for an evaluation of the elements within the domestic imbalance block with respect to the likelihood of a banking crisis for a hypothetical developed economy. The diagonal of this matrix will be all one, which implies that any component cannot be more or less likely than itself. Next, consider the entry in the cell for the comparison of the cashflow-to-investment ratio on the left and capacity utilization rates with a banking crisis at the top of the matrix. Under the current circumstances, the cashflow of businesses would greatly influence the likelihood of a banking crisis and hence the couplet is assigned the score of "5" on the 1-9 scale. By design, the comparison of capacity utilization and cashflow (row 1, column 2) will be equal to the reciprocal of the cashflow and capacity utilization evaluation (row 2, column 1), that is, 1/5 or 0.20. Similarly, paired comparison is used to build up the full matrix. Finally, the principal eigenvector provides the solution weights, which are shown in right-most column of Table 3.

Table 3. Comparisons for Domestic Imbalances

Comparisons for Domestic Imbalances with respect to Banking Crisis								
	Capacity Utilization	Cashflow-to-Investment	Consumer Debt Burden	Foreign Debt Reliance	Inventory-to-Sales Ratio	Labor Shortage	Profit Margins	Normalized Weights
Capacity Utilization	1.000	0.200	1.000	0.333	1.000	1.000	0.333	0.06975
Cashflow-to-Investment	5.000	1.000	3.000	1.000	3.000	3.000	3.000	0.29725
Consumer Debt Burden	1.000	0.333	1.000	0.333	1.000	1.000	0.333	0.07511
Foreign Debt Reliance	3.000	1.000	3.000	1.000	1.000	2.000	0.500	0.17459
Inventory-to-Sales Ratio	1.000	0.333	1.000	1.000	1.000	1.000	0.333	0.09065
Labor Shortage	1.000	0.333	1.000	0.500	1.000	1.000	1.000	0.09672
Profit Margins	3.000	0.333	3.000	2.000	3.000	1.000	1.000	0.19593
Inconsistency Index = 0.047 (Desirable value to be less than 0.10)								

The degree of logical inconsistency is also checked. The value of the inconsistency index is 0.047 or a modest 4.7% for this matrix of paired comparison, well below the 10% practical threshold above which the evaluations are reassigned. Of course, a consistent evaluation is not necessarily a correct evaluation of the risks. Priority weights are computed for the other 15

matrices in this model, using a comparable approach, and each matrix is checked for its degree of inconsistency.

Step 3: Construct and Solve the Supermatrix. The weights derived from steps 1 and 2 are used to populate the columns of the supermatrix. Each column of a supermatrix is either a normalized eigenvector with possibly some zero entries or all of its block entries are zero. The unweighted supermatrix, which is illustrated in the first panel of Table 4, is then multiplied by the priority weights from the clusters (which were determined in step 1), yielding the weighted supermatrix (second panel of Table 4). This is done because the resulting matrix must be column stochastic, that is its columns must add to one, for a limit that is not zero to exist.

Finally, the system solution is derived by multiplying the weighted supermatrix of model variables by itself, which accounts for variable interaction, until a stable result is obtained. When the matrix is irreducible, the powers of the matrix converge to a matrix whose columns are all the same. This "power method" process yields the limiting matrix, which provides the relative importance weights for every factor in the model. In our example, those weights are reported in the bottom panel of Table 4.

Now that the system weights have been determined, a financial-crisis turning point forecast could be derived using zero (0%) and one (100%) to represent no crisis or crisis (similar to the Radelet and Sachs model). This structured-judgmental forecast would be computed as Forecast Risk = 0.3841 x (Financial Crisis) + 0.6159 x (No Financial Crisis) = 0.3841 x 100% = 38.4% chance of a financial crisis within six months. Although the forecast probability is a "snapshot" at a point in time for a specific economy, it demonstrates the process of constructing a financial-crisis turning point forecast model using ANP.

Historical simulations based on rules for interpreting incoming information or expert-system rules could be used to back test the model for accuracy and to construct a time-dependent supermatrix (Saaty, 1994), if historical time series data exist. Moreover, sensitivity analysis – as demonstrated in Saaty (2001) – of the individual model components provides the user with bounds on how significant changes must be in order to impact a forecast (crisis or no crisis, in this case).

4. THE 1991 U.S. BANKING CRISIS

Now that we have sketched out the structure and mechanics of the ANP model, the remaining question is: How good is this model empirically, even though it captures the essence of previous econometric and judgmental forecasting research? Obviously, one shortcoming of judgmental forecasting is determining historical accuracy. Notwithstanding, it should be clear that we

offer the ANP framework as a method to structure one's thinking about financial-crisis triggers or catalysts, especially when data do not exist or given numerous intangibles, such as an unstable political climate and changes to the legal or regulatory structure.

The ANP method derives a judgmental forecast of the event risk given the evaluator's knowledge of the current situation, institutions, structural and political changes, and the expectation of change. This framework is conceptually very different from econometric or time-series model forecasts of financial-crisis risk, which are based on "historical statistical experience." These methods rarely are interchangeable, but they can be complementary.

It is impossible to fairly use a judgmental forecasting method, such as this ANP model, to back test how accurate the model "would have been" in signaling an event-driven financial crisis. Nonetheless, it is possible to test our model based on constructed decision rules, provided that historical data exist to derive them and largely ignoring purely judgmental information that may have been available at the time. Obviously, this test will compromise the true benefit of including pure intangibles, but it will test the validity of the model structure. Of course, nothing will replace real-time testing of a judgmental forecasting model, rule-based historical testing is a second-best solution, though Armstrong and Collopy (1998) observed that forecast rules can work well when trends are not persistent and there is good knowledge about the situation. Rules are used here as a proxy for judgmental decision making and they facilitate testing of the ANP model. Yet this relatively simplistic historical evaluation of the ANP model inputs using those rules can not prove the ANP model's accuracy, only its validity.

Our test of the ANP financial-crisis forecasting model is based on whether it signaled the January 1991 banking crisis in the U.S. economy as determined by Wolfson (1994). In lieu of human judgment, each indicator in the model was evaluated by the Goldstein et al. (2000) "signaling technique," whereby an optimal threshold for each criterion was derived based on its histogram, and a threshold signal was marked off when the value of the indicator crossed a given percentile. Thresholds were determined based on the individual indicator's distribution at 5%, 10%, 15%, 20% and 25%, if the lower bound was of interest, or when the upper bound in the distribution was of interest the threshold breakpoints were 75%, 80%, 85%, 90% and 95% where the indicator change signaled the crisis point. This approach assumes: (1) Observations falling in the lower or upper 25% or less of the distribution are considered to be signals of increased risk (where the nature of the series determines whether the upper tail or lower tail is relevant), (2) The strength of those signals will be determined by how much of an outlier the actual value is relative to its histogram (or fitted distribution), which is a proxy for "perceived impact," and (3) The signal rejection region (no crisis) is located in the remainder of the distribution. Our application of this threshold-search process was prompted by the successful use

of it by Goldstein, et al. (2000), in their determination of signals of financial vulnerability for emerging markets.

To implement the mechanical "pseudo-judgmental" evaluation (so as to allow for reproducibility) of historical information based on the fundamental evaluation scale, risk scores were assigned to observations based on how extreme the values were in the historical distribution for each series. Depending on whether an ANP model factor's lower tail or upper tail of the historical observations mattered (at least theoretically) for financial risk, the assigned risk scores and threshold points followed the rules shown in Table 5. For example, if the value of the current-account-deficit-to-GDP ratio (our empirical measure of foreign-debt reliance) was in the bottom 20% of the distribution, it was assigned a score of "5", but if it was in the bottom 5% of the distribution then it was assigned a score of "9" on the fundamental scale.

Finally, a decision-making rule was applied as a backtesting simplification based on the two outcomes or alternatives: "crisis" (100% chance) or "no crisis" (0% chance). This rule mapped risk scores greater than "6" on the 1-9 scale (based on the maximum reading over the current and three previous month's readings) to the crisis outcome and everything else to the no crisis scenario for the individual component under analysis. This procedure was applied to each component, as shown in Table 6, and for each period.

Over the 1990 to 1992 period, the sequential model evaluation by those decision rules showed that the overall probability of a financial crisis rose from essentially zero earlier in 1990 to about 80% by October 1990, which seemingly would have warned of some looming form of financial crisis. The more specific probability of a banking crisis, meanwhile, which was less than 20% at the beginning of 1990 grew to over 60% by mid 1990, then receded a bit and rose to a peak of over 70% by March 1991. Wolfson's research determined that the beginning of the banking crisis was January 1991. As such, the model captured the growing banking-crisis risk during 1990, though its peak risk level occurred after the actual turning point date. The results are displayed in Figure 2.

Although this empirical test of the ANP crisis-forecasting model was very encouraging, we must underscore the point that it is only illustrative of capturing the crisis dynamic within an ANP framework. The full power of the ANP framework was compromised necessarily by this backtesting exercise. Nevertheless, as a test of the mathematical structure of this model and the logic embodied in it, these results using the imbalance-crisis-turning-point model were very encouraging.

Table 5. Backtesting rule for assigning risk scores using "Signaling Technique" Evaluating incoming information on Saaty' scale based on histogram

Assigned Saaty Score	Threshold for Upper Tail of Distribution	Threshold for Lower Tail of Distribution
1	Less than 75%	Greater than 25%
3	Equal to 75% but Less than 80%	Equal to 25% but Greater than 20%
5	Greater than 80% but Less than 85%	Less than 20% but Greater than 15%
7	Greater than 85% but Less than 90%	Less than 15% but Greater than 10%
8	Greater than 90% but Less than 95%	Less than 10% but Greater than 5%
9	Greater than 95%	Less than 5%

Table 6. Variables used to backtest the ANP model

Variable/Concept	Form	Average	Std. Dev.	Max	Min
Wholesale Energy Prices	Monthly Percentage Change	0.6%	2.8 pp.	13.4%	-14.0%
Wholesale Food Prices	Monthly Percentage Change	0.2%	1.1 pp.	9.5%	-3.3%
Productivity	Quarterly Percentage Change (AR)	2.1%	3.6 pp.	13.3%	-5.9%
Profit Margin	First Difference	0.0 pts.	0.4 pts.	1.3 pts.	-2.3 pts.
Inventory/Sales Ratio	Growth (TQSAR)	-0.33%	2.52 pp.	6.63%	-7.84%
Corp. Financing Ability	Cashflow-to-Investment ratio	0.801%	0.078 pp.	0.955%	0.600%
Consumer Debt	Monthly Percentage Change	0.7%	0.5 pp.	2.3%	-1.4%
Unemployment Rate	Level	5.7%	1.58 pp.	10.8%	2.5%
Capacity Utilization Rate	Level	82.1%	3.52 pp.	89.4%	71.1%
Current Account	Current Account to GDP Ratio	-0.8%	1.4 pp.	1.3%	-4.5%
Monetary Policy	Change in Fed Funds Rate	0.0 pt.	0.6 pp.	3.1 pts.	-6.6 pts.
Tax Policy	Effective Tax Rates (Corp. + Personal)	62.6 pts.	12.1 pp.	86.7 pts.	47.7 pts.
Banking	Nonfin. Corp. Credit Mkt Borrowing %	8.8%	3.8 pp.	17.1%	-3.1%
Fiscal	Federal Deficit/GDP Ratio	-1.39%	2.0 pp.	2.5%	-6.4%
Currency	Trade-Weighted Dollar Growth	5.5%	6.86 pp.	24.3%	-10.0%
Contagion	Change in Export and Import Shares	2.7%	7.3 pp.	37.4%	-17.9%

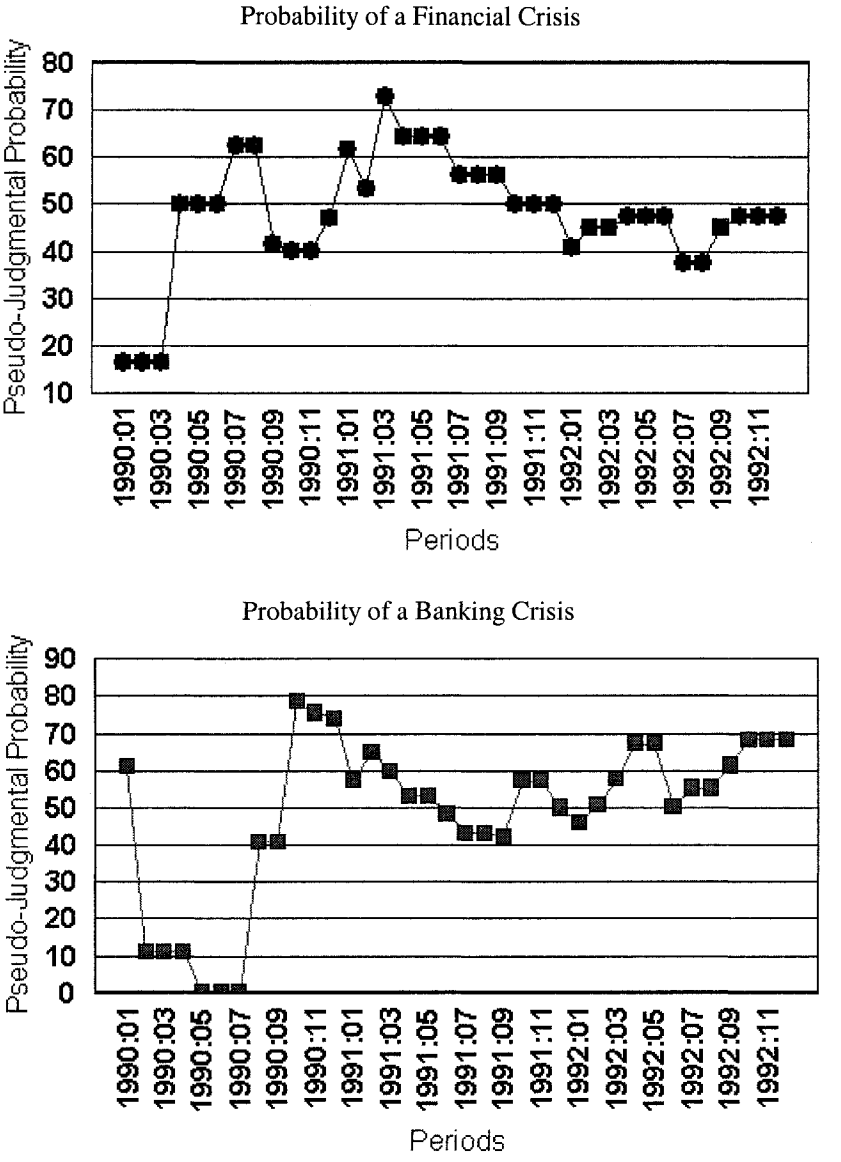

Figure 2. Financial-Crisis Model Backtesting Exercise

5. CONCLUSION

As a practical matter, Kahneman and Tversky (1973) observed that, "In making predictions and judgments under uncertainty, people do not appear to follow the calculus of chance or the statistical theory of prediction. Instead, they rely on a limited number of heuristics." This especially may be true when data limitations make a timely statistical forecast impossible. However, ANP offers a judgmental forecasting structure to evaluate those heuristics in a consistent manner. The model was back tested for a period in the early 1990s when there was a banking crisis in the United States. It was not our intent to evaluate any individual forecaster's ability or collective forecasting accuracy, per se, but to evaluate the potential robustness of the crisis forecasting model's structure, which in turn might be used for real-time judgmental forecasting. We found that the ANP model approach indeed was a promising methodology to forecast the likelihood of event-driven cycles.

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CHAPTER 4

OUTSOURCING A FIRM'S APPLICATION DEVELOPMENT GROUP

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(Winter 2004)

1. INTRODUCTION

Outsourcing Information Technology (IT) functions is a growing trend in businesses looking for ways to reduce cost and hasten time-to-market of customer-facing and internal applications. The strategy of outsourcing functions, tasks, and activities to another company has existed for decades. During periods of recession, U.S. corporations cut costs by moving jobs that are of a repetitive nature to lower-cost regions, typically "offshore" or in non-U.S. countries. For example, manufacturing companies have been leveraging offshore resources since the 1950s, while the off-shoring of IT started about 10-15 years ago with the movement of legacy system maintenance tasks to Ireland and Canada. According to Bart Perkins, Computer World, businesses are now looking towards outsourcing for three reasons: budget pressures, a view of IT as a "no win" function, and the existence of specialized service providers. Many firms continue to face budget constraints with budgets remaining flat and most firms looking to reduce costs. In some cases, the IT function is viewed as a utility that can and should be outsourced. With the rapid changes in technology, it is difficult for in-house developers to match the skill sets of outsourcers with specialized, targeted skills, making it more attractive to outsource development activities in order to keep up with improvements in technology. Given these views, many businesses are resurrecting the interest in outsourcing.

IT outsourcing seems to be easier than ever to accomplish: telecommunications have improved drastically, enabling better productivity of a remote workforce; geographic distances are becoming more transparent with use of collaboration tools available today, such as online web meetings and improved video conferencing technology. And who can argue with the obvious personnel and IT asset cost reduction opportunities associated with this strategy? All of this, however, must be tempered with the soft costs and risks inherent in moving a firm's codified business processes to a potentially insecure, unstable environment.

The decision model network and judgments discussed below are based upon research, as cited in the References section of this chapter.

2. THE MODEL

The objective or goal of this model is to address the question: "How should companies staff their application development function?" The model includes the benefits, opportunities, costs, and risks involved in making this decision. Further details appear below.

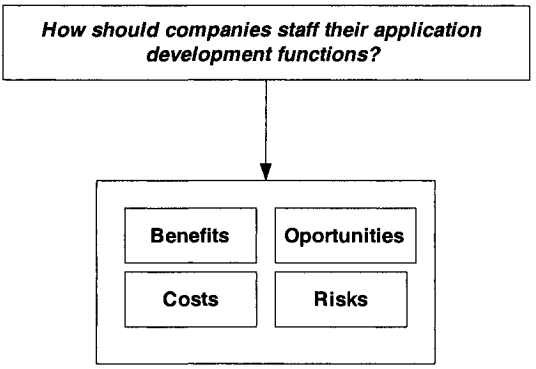
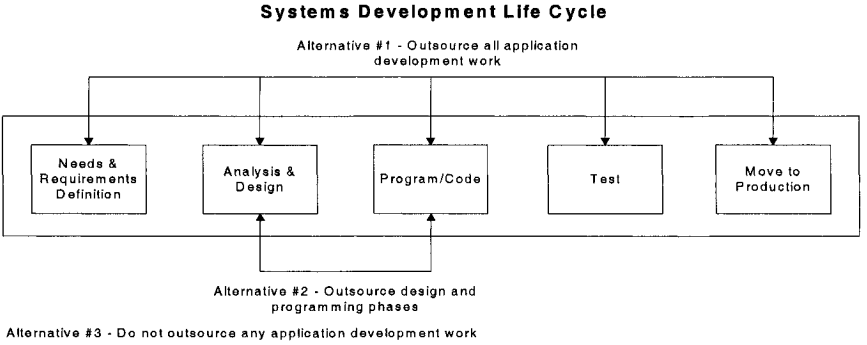


Figure 1. BOCR model

Alternatives:

1. Outsource all application development work
2. Outsource the design and programming phases
3. Do not outsource any application development work



Merits:

The merits and elements used in the model are described below and shown in the following table (Table 1).

Table 1. Clusters in the Decision Networks and Elements in the Clusters

BOCR	Control Criteria	Clusters	Elements in Clusters
Benefits	Economic	Financial	1 IT assets, 2 Personnel, 3 Legal
		Operational	1 Time to finish project / job, 2 Use of project management, 3 Knowledge transfer during requirements def, 4 Control / influence over human resources, 5 Fast time-to-market
	Technological	Technology	1 Leverage solutions from prev. business problems, 2 Newest technology available
		Resources	1 Knowledge of latest technologies, 2 Immediately available
Opportunities	Customer - related	Customer base	1 Grow into other countries, 2 Customer retention
		Marketing	1 Agile, quick response to customer requests, 2 New features / functionality
	Economic	Business development	1 Expansion into foreign countries, 2 Expand product line
		Financial	1 Make investments, 2 Reduce debt
		Employees	1 Focus - quality assurance of software, 2 Focus - firm's core capabilities, 3 Focus - software alignment with business, 4 Productivity
Costs	Economic	Financial	1 IT assets, 2 Personnel, 3 Legal
		Operational	1 Time to finish project / job, 2 Use of project management, 4 Knowledge transfer during requirements def, 4 Control / influence over human resources, 5 Time-to-market
		Resources	1 Knowledge of latest technologies, 2 Immediately available
	Social	Stakeholders	1 Company shareholders perception, 2 Media criticism, 3 Company executives / managers perception, 4 Company employees perception
		Labor	1 US unemployment, 2 Employee morale, 3 Control / influence over human resources, 4 Productivity
Risks	Economic	Financial	1 Legal costs
		Business processes	1 Business process knowledge, 2 Business continuity, 3 Quality assurance
		Security	1 Physical, 2 Intellectual property, 3 Geopolitical environment - stability
		Communication	1 Geographic distance, 2 Communication tool availability - email voice mail, 3 H-1B and L-1 visa availability, 4 Language differences
	Social	Labor	1 Employee morale, 2 Productivity, 3 US unemployment
		Stakeholders	1 Company shareholders perception, 2 Media criticism, 3 Company executives / managers perception, 4 Company employees perception
All networks	Alternatives		1 Outsource all application development work,
			2 Outsource the design and programming phases,
			3 Do not outsource any application development work

Benefits

Economic and Technological benefits were identified for this portion of the model (Figure 2).

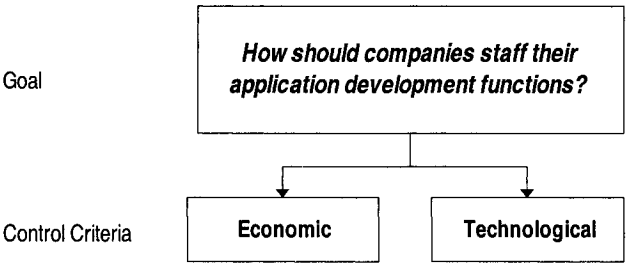


Figure 2. Benefits model

Under Economic benefits, there are two clusters: Financial and Operational (See Figure 3). These clusters include the following nodes.

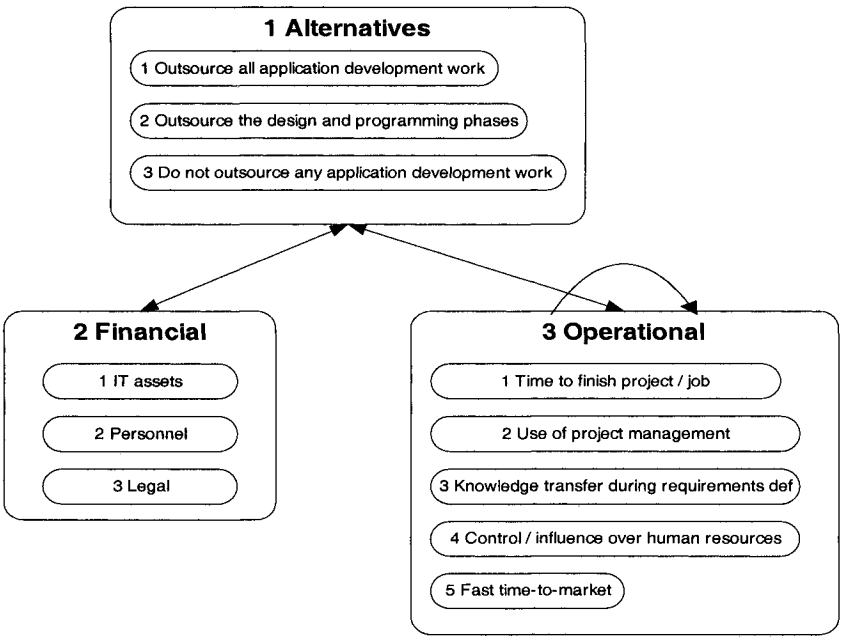


Figure 3. Clusters with elements under Economic Benefits

- Financial nodes: IT assets, Personnel, and Legal. IT Assets refers to the reduction of IT infrastructure costs such as workstations, servers, and licensing; Personnel refers to the reduction of costs for activities such as salaries, health insurance, pension benefits; Legal refers to the avoidance of costs associated with contract negotiations.
- Operational nodes: Time to finish project/job, Use of project management, Knowledge transfer during requirements definition, Control/influence over human resources, and Fast time-to-market. The

concepts behind these items are rather self-explanatory; however to expand upon a couple may be necessary. Knowledge transfer during requirements definition is a key item when it comes to documenting system and application requirements and communicating those effectively to the persons programming and testing the application. Fast time-to-market relates to an enterprise's ability to quickly and with agility, meet its customer needs and wants through use of IT solutions.

Under Technological benefits, there are also two clusters: Technology and Resources (see Figure 4). These clusters include the following nodes.

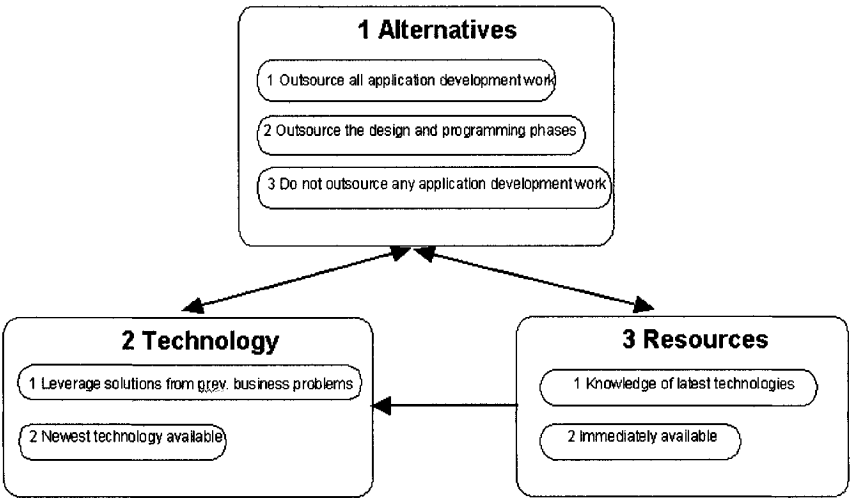


Figure 4. Clusters with elements under Technological Benefits

- Technology nodes: Leverage solutions from previous business problems and newest technologies available. The first item relates to an application development group's ability to take what it has learned from solving similar or other business problems in the past, and leveraging or applying that experience to a current or new problem. The second item relates to an enterprise being able to take advantage of newer technologies without a lot of cost to the firm in terms of ramping up its IT infrastructure.
- Resources nodes: Knowledge of latest technologies and immediately available. These speak to the human resource aspect of technology benefits in that people are knowledgeable in the newest ways to use technology and these people are readily available to work on a new high priority project.

Opportunities

Economic and Customer-related opportunities were identified for this portion of the model (see Figure 5).

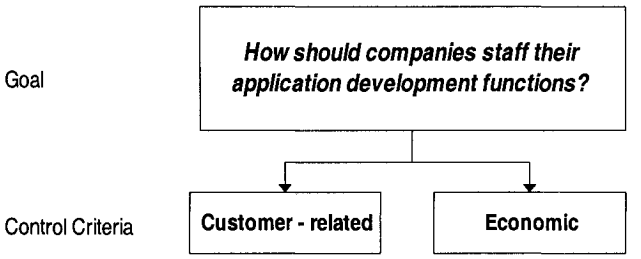


Figure 5. Opportunities model

Under Economic opportunities, there are three clusters: Business development, Financial, and Employees (see Figure 6). These clusters include the following nodes.

- Business development nodes: Expansion into foreign countries and Expand product line. Expanding into foreign countries is an opportunity when outsourcing with non-U.S. vendors. Expanding product line may be a stretch, but it is identified as an opportunity because the cost reduction provided by outsourcing may enable expansion of a firm's offering.
- Financial nodes: Make investments and Reduce debt. Opportunities to engage in these financial activities may be present more readily when outsourcing as opposed to not outsourcing (i.e., rather than investing in a firm's own IT assets and personnel, the firm may identify an opportunity to invest money saved through outsourcing.)
- Employees nodes: Focus-quality assurance of software, Focus-firm's core capabilities, Focus-software alignment with business, and Productivity. The three "focus" opportunities identified relate to having IT employees concentrate on these value-added competencies rather than focusing on the tasks of programming or coding. An opportunity to increase productivity among employees may also be present when outsourcing.

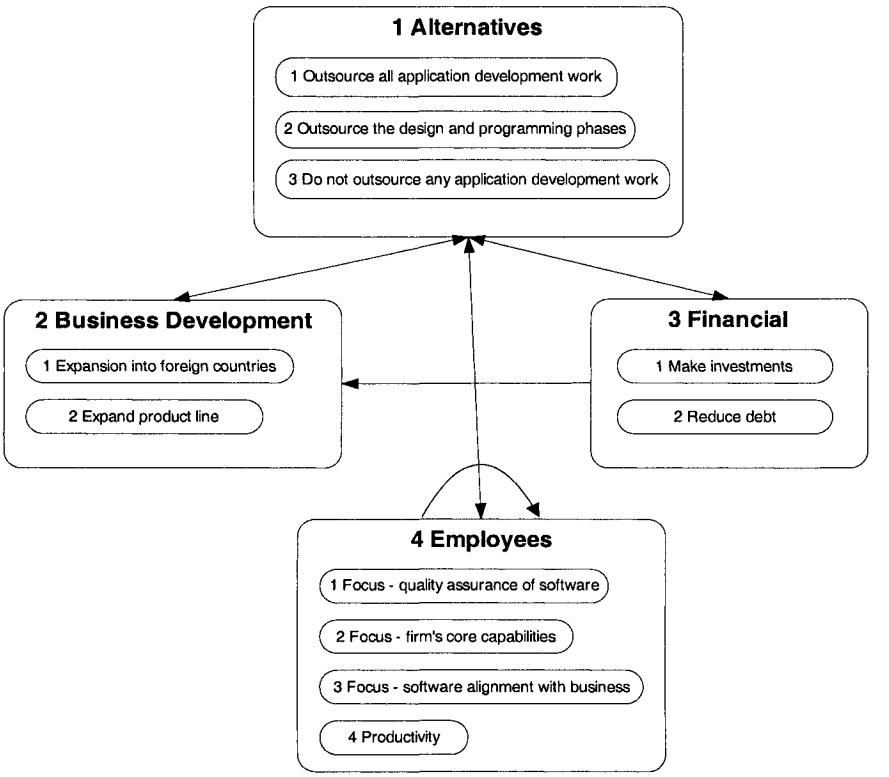


Figure 6. Clusters with elements under Economic Opportunities

Under Customer-related opportunities, there are two clusters: Customer base and Marketing (see Figure 7). These clusters include the following nodes.

- Customer base nodes: Grow into other countries and Customer retention. Expansion of customer base by growing into other countries may be an opportunity with respect to the outsourcing alternatives. By meeting (exceeding) customer business needs and requirements through technology, a firm has an opportunity to better retain its existing customers.
- Marketing nodes: Agile, quick response to customer requirements and New features/functionality. By having an applications development process that is able to quickly address customer requirements, a firm has an opportunity to improve its marketing to new and existing customers. New features/functionality in an application can be marketed and present another customer-based opportunity for the firm.

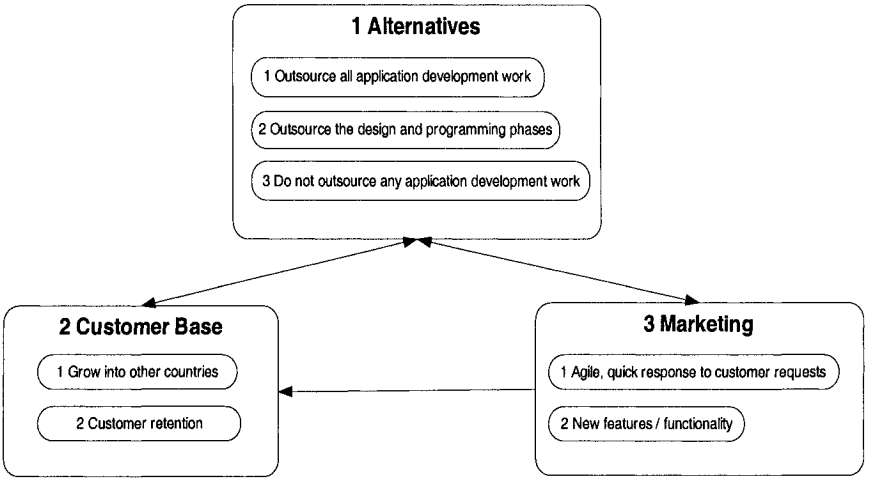


Figure 7. Clusters with elements under Customer-related Opportunities

Costs

Economic and Social costs were identified for this portion of the model (see Figure 8).

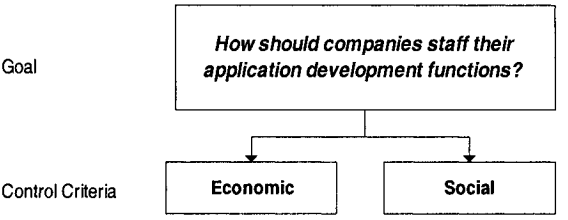


Figure 8. Costs model

Under Economic costs, there are three clusters: Financial, Operational, and Resources (see Figure 9). These clusters include the following nodes.

- Financial nodes: IT Assets, Personnel, and Legal. IT Assets refers to the cost of retaining IT infrastructure for things such as workstations, servers, and licensing. Personnel refers to the retention of costs for things such as salaries, health insurance, pension benefits; Legal refers to the accumulation of costs associated with contract negotiations.
- Operational nodes: Time to finish project/job, Use of project management, Knowledge transfer during requirements definition, Control/influence over human resources, and Fast time-to-market. In terms of cost, the first four items' cost increases with outsourcing. They are interrelated with or

without outsourcing. Fast time-to-market relates to an enterprise's ability to quickly and with agility, meet its customer needs and wants through use of IT solutions. Without outsourcing, this becomes a cost.

- Resources nodes: Knowledge of latest technologies and availability. Without outsourcing, these two items become costs; resources with knowledge of the latest technologies may not be available quickly.

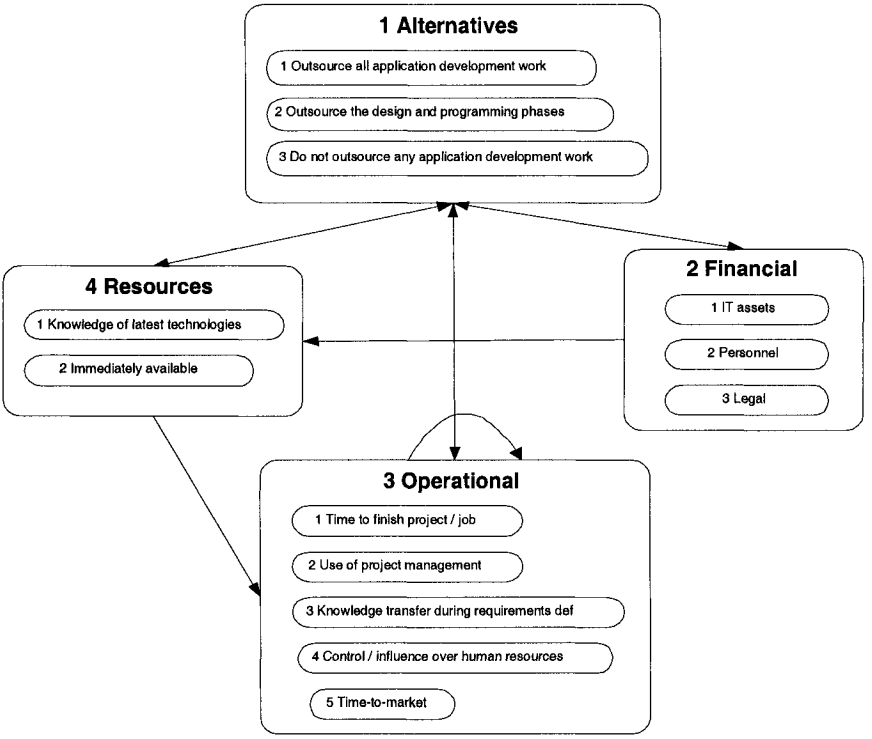


Figure 9. Clusters with elements under Economic Costs

Under Social costs, there are two clusters: Stakeholders and Labor (see Figure 10). These clusters include the following nodes.

- Stakeholders nodes: Company shareholders' perception, Media criticism, Company executives/managers' perception and Company employees' perception. These four nodes are rather self-explanatory and represent the various stakeholders' perceptions' influence on this decision.
- Labor nodes: U.S. unemployment, Employee morale, Control/influence over human resources and Productivity. Again, these nodes are rather self-explanatory in terms of costs for the alternatives.

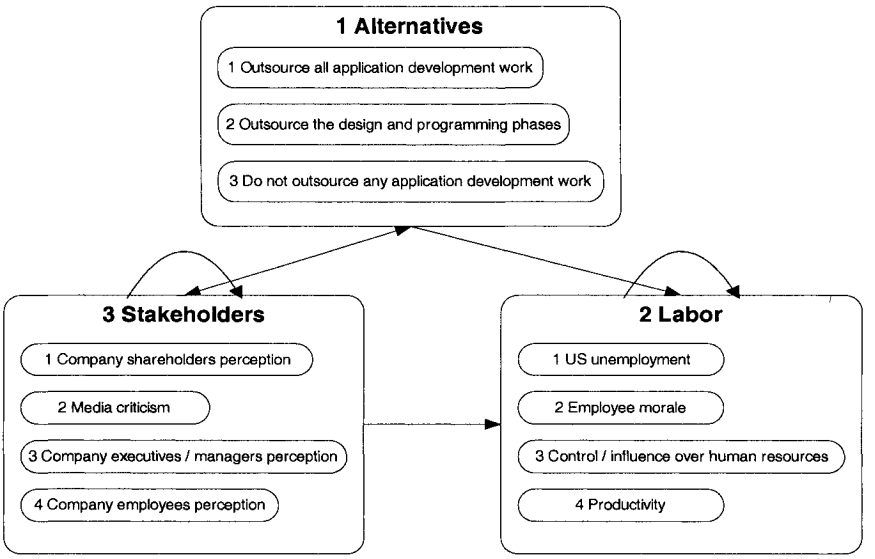


Figure 10. Clusters with elements under Social Costs

Risks

Economic and Social risks were identified for this portion of the model (see Figure 11).

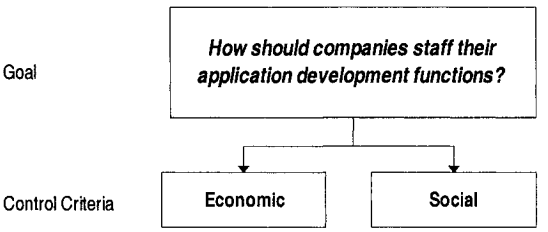


Figure 11. Risks model

Under Economic risks, there are four clusters: Financial, Security, Communication and Business processes (see Figure 12). These clusters include the following nodes.

- Financial node: Legal costs. The risk of incurring legal costs is represented here.
- Security nodes: Physical, Intellectual property, and Geopolitical environment – stability. The risk to the physical security of servers and other IT equipment is represented through the Physical node. The

Intellectual property node represents the risk of losing control or ownership of programs and software written for an enterprise. The Geopolitical environment risk pertains to the increased risk of outsourcing a firm's programming function to an area of the world that is or soon may be at war.

- Communication nodes: Geographic distance, Communication tool availability –email/voice mail, H-1B and L-1 visa availability and Language differences. Distance, communication tool availability, and language differences represent the risks of poor communication as a result of outsourcing. With the risk that H-1B and L-1 visas will be limited, a firm may have a much more difficult time bringing in foreign outsourcers to work closely and communication with its U.S.-based personnel.
- Business processes nodes: Business process knowledge, Business continuity, and Quality assurance. By outsourcing the areas represented by these nodes reflects the risk that any of these could suffer.

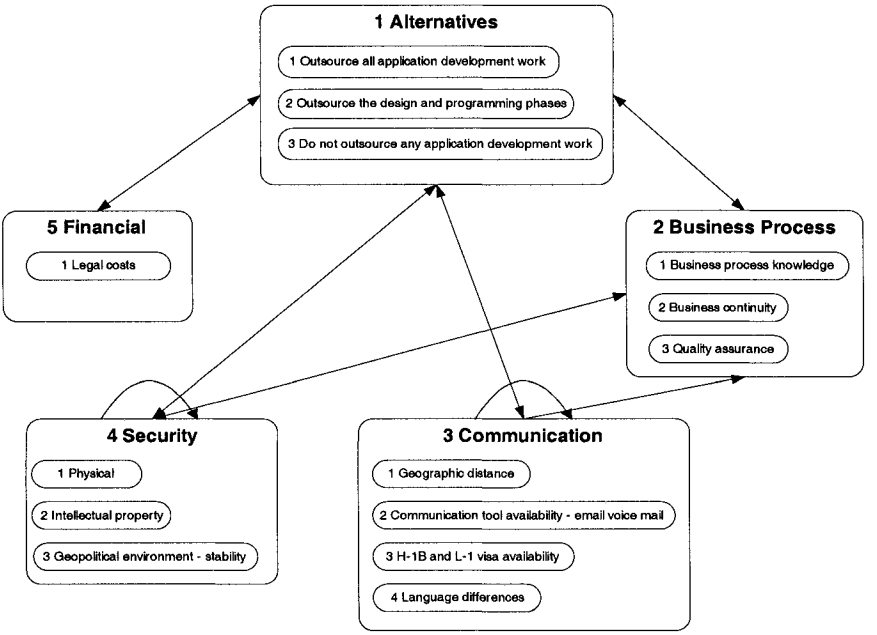


Figure 12. Clusters with elements under Economic Risks

Under Social risks, there are two clusters: Labor and Stakeholders (see Figure 13). These clusters include the following nodes.

- Labor nodes: Employee morale, Productivity and U.S. unemployment. These nodes are rather self-explanatory in terms of risks and influence on the alternatives.

- Stakeholders nodes: Company shareholders' perception, Media criticism, Company executives/managers' perception, and Company employees' perception. These four nodes are rather self-explanatory and represent the various stakeholders' perceptions' influence on this decision in terms of risk.

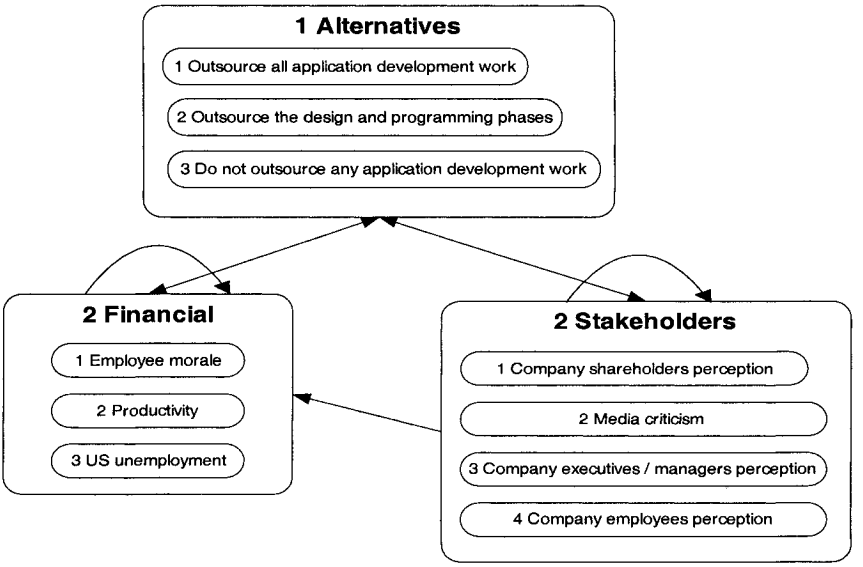


Figure 13. Clusters with elements under Social Risks

3. BOCR PRIORITIES

The elements under each of the BOCR merits received priorities through pairwise comparisons as shown in Table 2. Table 3 represents priorities for the ideal alternatives under each BOCR control criterion.

To obtain the priorities of Table 2, we fist prioritize the clusters constituting the subnets under the control criteria corresponding to each of the merits. For example, consider Figure 3. Under the control criterion Economic benefits there are three clusters, Alternatives, Financial and Operational. The influence of a cluster on the other clusters is represented in matrix form in Table 3. Thus, the Alternatives cluster is influenced by Financial and Operational clusters (column 1 in Table 3), Financial is influenced by the Alternatives (column 2) and Operational is influenced by the Alternatives and itself (column 3).

Table 2. Criteria and Elements with Their Priorities

BOCR	Criteria	Clusters	Elements	Local priorities	Global priorities
Benefits	Economic 0.8333	Alternatives	1 Outsource all application dev. func.	0.5824	0.2821
			2 Outsource the design...	0.2166	0.1048
			3 Do not outsource	0.211	0.0974
		Financial	1 IT assets	0.4505	0.1091
			2 Personnel	0.1758	0.0426
			3 Legal	0.3737	0.0905
		Operational	1 Time to finish project / job	0.1745	0.0477
			2 Use of project management	0.2296	0.0628
			3 Knowledge transfer during requirements def	0.2274	0.0628
			4 Control / influence over human resources	0.1209	0.0331
			5 Fast time-to-market	0.2475	0.0677
	Technological 0.1667	Alternatives	1 Outsource all application dev. func.	0.4437	0.2168
			2 Outsource the design...	0.4437	0.0168
			3 Do not outsource	0.1126	0.055
		Resources	1 Knowledge of latest technologies	0.1852	0.0453
			2 Immediately available	0.8148	0.1991
		Technology	1 Leverage solutions from prev. business	0.8	0.2136
			2 Newest technology available	0.2	0.0534
Opportunities	Customer - related 0.25	Alternatives	1 Outsource all application dev. func.	0.4573	0.2033
			2 Outsource the design...	0.3748	0.1666
			3 Do not outsource	0.1679	0.0746
		Customer base	1 Grow into other countries	0.2848	0.0949
			2 Customer retention	0.7152	0.2384
		Marketing	1 Agile, quick response to customer requests	0.8333	0.1852
			2 New features / functionality	0.1667	0.037
	Economic 0.75	Alternatives	1 Outsource all application dev. func.	0.4362	0.2053
			2 Outsource the design...	0.3381	0.1592
			3 Do not outsource	0.2257	0.1062
		Business development	1 Expansion into foreign countries	0.5	0.0828
			2 Expand product line	0.5	0.0828
		Financial	1 Make investments	0.6667	0.1104
			2 Reduce debt	0.3333	0.0552
		Employees	1 Focus - quality assurance of software	0.3121	0.0619
			2 Focus - firm's core capabilities	0.2291	0.0454
			3 Focus - software alignment with business	0.2639	0.0523
			4 Productivity	0.1948	0.0386

Table 2 (cont.)

BOCR	Criteria	Clusters	Elements	Local priorities	Global priorities
Costs	Economic 0.8333	Alternatives	1 Outsource all application dev. func.	0.2882	0.1307
			2 Outsource the design...	0.2797	0.1268
			3 Do not outsource	0.432	0.1958
		Financial	1 IT assets	0.2631	0.0398
			2 Personnel	0.5472	0.0827
			3 Legal	0.1897	0.0287
		Operational	1 Time to finish project / job	0.2458	0.0601
			2 Use of project management	0.1457	0.0356
			4 Knowledge transfer during requirements def	0.2168	0.053
			4 Control / influence over human resources	0.0832	0.0203
			5 Time-to-market	0.3084	0.0754
		Resources	1 Knowledge of latest technologies	0.2589	0.0391
			2 Immediately available	0.7411	0.112
	Social 0.1667	Alternatives	1 Outsource all application dev. func.	0.3682	0.1003
			2 Outsource the design...	0.3416	0.0931
			3 Do not outsource	0.2902	0.0791
		Stakeholders	1 Company shareholders perception	0.1486	0.0379
			2 Media criticism	0.2695	0.0687
			3 Company executives / managers perception	0.2261	0.0577
			4 Company employees perception	0.3558	0.0907
		Labor	1 US unemployment	0.0621	0.0294
			2 Employee morale	0.2995	0.1415
			3 Control / influence over human resources	0.1204	0.0569
			4 Productivity	0.518	0.2448
Risks	Economic 0.75	Alternatives	1 Outsource all application dev. func.	0.4332	0.1979
			2 Outsource the design...	0.4332	0.1979
			3 Do not outsource	0.1336	0.061
		Financial	1 Legal costs	1	0.1142
		Business process	1 Business process knowledge	0.2744	0.0475
			2 Business continuity	0.4423	0.0765
			3 Quality assurance	0.2833	0.049
		Security	1 Physical	0.2741	0.0345
			2 Intellectual property	0.4452	0.0561
			3 Geopolitical environment - stability	0.2807	0.0354
		Communication	1 Geographic distance	0.0823	0.0107
			2 Communication tool availability - email voice mail	0.3638	0.0473
			3 H-1B and L-1 visa availability	0.2163	0.0281
			4 Language differences	0.3376	0.0439
	Social 0.25	Alternatives	1 Outsource all application dev. func.	0.3779	0.1591
			2 Outsource the design...	0.3779	0.1591
			3 Do not outsource	0.2442	0.1028
		Labor	1 Employee morale	0.4654	0.154
			2 Productivity	0.3874	0.1282
			3 US unemployment	0.1472	0.0487
		Stakeholders	1 Company shareholders perception	0.1486	0.0369
			2 Media criticism	0.2298	0.057
			3 Company executives / managers perception	0.3939	0.0977
			4 Company employees perception	0.2276	0.0564

Table 3. Clusters Influences

Economic	Alternatives	Financial	Operational
Alternatives	0	x	x
Financial	x	0	0
Operational	x	0	x

These influences are prioritized by asking the question: For the control criterion in question, in this case Economic benefits, given a cluster, for example, the Alternatives, which cluster influences it more, Financial or Operational, and how much more? The result is the following matrix of paired comparisons:

Alternatives	Financial	Operational	Priorities
Financial	1	5	0.8333
Operational	1/5	1	0.1667

Comparing all the clusters yields the matrix of priorities given in Table 4.

Table 4. Clusters Priorities

	Alternatives	Financial	Operational
Alternatives	0	1	0.3333
Financial	0.8333	0	0
Operational	0.1667	0	0.6667

Next, the elements in a cluster are prioritized with respect to the elements of the other clusters that have an influence on it. For example, for the economic control criterion, given Alternative 1, Outsource all application development work, and two elements in the Financial cluster, for example, IT Assets and Personnel, which element influences Alternative 1 more and how much more? The answer to this question is given in the (1, 2) position in Table 5. The result is the matrix of paired comparisons given in Table 5.

Table 5. Relative Influence of Financial Elements on Alternative 1

Outsource all application development work	IT Assets	Personnel	Legal	Priorities
IT Assets	1	4	1	0.4579
Personnel	1/4	1	1/3	0.1260
Legal	1	3	1	0.4161

The priorities from Table 5 are inserted in the matrix given in Table 6 in the highlighted block (F, A1). Next these priorities are multiplied by the weight of the cluster in the cell (Financial, Alternatives) from Table 4. The result is the highlighted block (F, A1) in Table 7. This table is now used to obtain the limiting priorities of the elements in the clusters under the control criterion Economic benefits (Table 8). The priorities of the alternatives are then idealized by dividing by the largest priority (Table 9).

Table 6. Unweighted Supermatrix

			A			F			O				
			A1	A2	A3	F1	F2	F3	O1	O2	O3	O4	O5
A	A1	Outsource all application development work,	0	0	0	0.7536	0.7536	0.7536	0.6267	0.5584	0.0881	0.0914	0.6442
	A2	Outsource the design and programming phases,	0	0	0	0.1811	0.1811	0.1811	0.2797	0.3196	0.1947	0.2176	0.2706
	A3	Do not outsource any application development work	0	0	0	0.0653	0.0653	0.0653	0.0936	0.1220	0.7172	0.6910	0.0852
F	F1	IT Assets	0.4579	0.5396	0.3333	0	0	0	0	0	0	0	0
	F2	Personnel	0.1260	0.1634	0.3333	0	0	0	0	0	0	0	0
	F3	Legal	0.4161	0.2970	0.3333	0	0	0	0	0	0	0	0
O	O1	Time to Finish	0.1853	0.2232	0.0773	0	0	0	0	0.1958	0	0	0
	O2	Use of Project Mgmt.	0.3455	0.1159	0.1643	0	0	0	0	0	0	0	0
	O3	Knowledge Transfer	0.1132	0.2605	0.3512	0	0	0	0	0.4934	0	0	0
	O4	Control	0.0602	0.0995	0.1973	0	0	0	0	0.3108	0	0	0
	O5	Fast Time-to-market	0.2958	0.3009	0.2098	0	0	0	0	0	0	0	0

Table 7. Weighted Supermatrix

			A			F			O				
			A1	A2	A3	F1	F2	F3	O1	O2	O3	O4	O5
A	A1	Outsource all application development work,	0	0	0	0.7536	0.7536	0.7536	0.6267	0.1861	0.0881	0.0914	0.6442
	A2	Outsource the design and programming phases,	0	0	0	0.1811	0.1811	0.1811	0.2797	0.1065	0.1947	0.2176	0.2706
	A3	Do not outsource any application development work	0	0	0	0.0653	0.0653	0.0653	0.0936	0.0407	0.7172	0.6910	0.0852
F	F1	IT Assets	0.3815	0.4497	0.2778	0	0	0	0	0	0	0	0
	F2	Personnel	0.1050	0.1362	0.2778	0	0	0	0	0	0	0	0
	F3	Legal	0.3468	0.2475	0.2778	0	0	0	0	0	0	0	0
O	O1	Time to Finish	0.0309	0.0372	0.0129	0	0	0	0	0.1305	0	0	0
	O2	Use of Project Mgmt.	0.0576	0.0193	0.0274	0	0	0	0	0	0	0	0
	O3	Knowledge Transfer	0.0189	0.0434	0.0586	0	0	0	0	0.3289	0	0	0
	O4	Control	0.0100	0.0166	0.0329	0	0	0	0	0.2072	0	0	0
	O5	Fast Time-to-market	0.0493	0.0502	0.0350	0	0	0	0	0	0	0	0

Table 8. Limiting Supermatrix

			A			F			O				
			A1	A2	A3	F1	F2	F3	O1	O2	O3	O4	O5
A	A1	Outsource all application development work.	0.34274	0.34274	0.34274	0.3427	0.3427	0.3427	0.3427	0.3427	0.3427	0.3427	0.3427
	A2	Outsource the design and programming phases.	0.09482	0.09482	0.09482	0.0948	0.0948	0.0948	0.0948	0.0948	0.0948	0.0948	0.0948
	A3	Do not outsource any application development work	0.05475	0.05475	0.05475	0.0548	0.0548	0.0548	0.0548	0.0548	0.0548	0.0548	0.0548
F	F1	IT Assets	0.1886	0.1886	0.1886	0.18862	0.18862	0.18862	0.18862	0.18862	0.18862	0.18862	0.18862
	F2	Personnel	0.0641	0.0641	0.0641	0.06411	0.06411	0.06411	0.06411	0.06411	0.06411	0.06411	0.06411
	F3	Legal	0.1575	0.1575	0.1575	0.15752	0.15752	0.15752	0.15752	0.15752	0.15752	0.15752	0.15752
O	O1	Time to Finish	0.0178	0.0178	0.0178	0.01783	0.01783	0.01783	0.01783	0.0178	0.01783	0.01783	0.01783
	O2	Use of Project Mgmt.	0.0231	0.0231	0.0231	0.02307	0.02307	0.02307	0.02307	0.02307	0.02307	0.02307	0.02307
	O3	Knowledge Transfer	0.0214	0.0214	0.0214	0.02138	0.02138	0.02138	0.02138	0.0214	0.02138	0.02138	0.02138
	O4	Control	0.0116	0.0116	0.0116	0.01159	0.01159	0.01159	0.01159	0.0116	0.01159	0.01159	0.01159
	O5	Fast Time-to-market	0.0236	0.0236	0.0236	0.02357	0.02357	0.02357	0.02357	0.02357	0.02357	0.02357	0.02357

Table 9. Priorities of the alternatives for Economic Benefits in Ideal Form

Alternatives	Priorities (ideal form)
Outsource all application development work.	1
Outsource the design and programming phases.	0.2767
Do not outsource any application development work	0.1597

Doing this for all the control criteria yields Table 10. The synthesized priorities for the merits are given in Table 11.

Table 10. Priorities for Alternatives under BOCR Control Criteria

	Benefits		Opportunities		Costs		Risks	
Alternatives	Econ. (0.8333)	Techn. (0.1667)	Cust.–rel. (0.2500)	Econ. (0.7500)	Econ. (0.8333)	Soc. (0.1667)	Econ. (0.7500)	Soc. (0.2500)
1 Outsource all application development work	1	1	1	1	0.7975	1	1	1
2 Outsource the design and programming phases	0.2766	1	0.8655	0.8151	0.7122	0.9195	1	1
3 Do not outsource any application development work	0.1597	0.2669	0.3477	0.5385	1	0.8552	0.2944	0.5446

Table 11. Priorities for Alternatives under BOCR

Alternatives	Benefits	Opportunities	Costs	Risks
1 Outsource all application development work	1	1	0.8313	1
2 Outsource the design and programming phases	0.3972	0.8277	0.7468	1
3 Do not outsource any application development work	0.1776	0.4908	0.9759	0.3570

The next step is to identify the **Strategic criteria** (shown in Figure 14):

1. Financial
2. Technology: a) Availability of experts
   b) Flexibility
3. Time-to-market
4. Social: a) Media perception
   b) Shareholder & employee perception

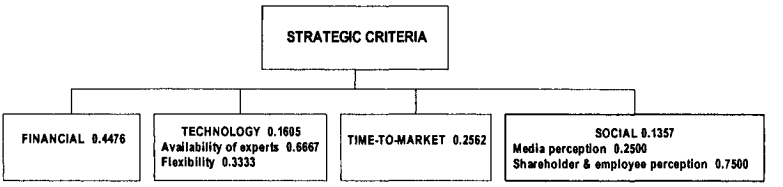


Figure 14. Strategic criteria

The **ratings scale** shown in Table 12 was used to rate BOCR with respect to the strategic criteria using the top ranked alternative for each merit.

The **merits' ratings** using the top ranked alternative for each merit are given in Table 13.

Table 12. Strategic criteria scale for ratings - priorities (ideals)

Financial 0.4476	**Availability of experts** 0.1070	**Flexibility** 0.0535	**Time–to-market** 0.2562	**Media perception** 0.0339	**Shareholder & employee perception** 0.1018
High possibility to reduce costs 0.5909 (1.0000)	Immediately 0.6267 (1.0000)	Hi 0.6267 (1.0000)	Fast 0.4626 (1.0000)	Very supportive 0.4626 (1.0000)	Very supportive 0.4626 (1.0000)
Moderate possibility to reduce costs 0.2754 (0.4660)	Moderately 0.2797 (.4463)	Medium 0.2797 (0.4463)	Moderately fast 0.3073 (0.6643)	Moderately supportive 0.3073 (0.6643)	Moderately supportive 0.3073 (0.6643)
Somewhat unlikely to reduce costs 0.0905 (0.1531)	Delayed 0.0936 (1494)	Low 0.0936 (0.1494)	Average 0.1416 (0.3061)	Neutral 0.1416 (0.3061)	Neutral 0.1416 (0.3061)
Unlikely to reduce costs 0.0432 (0.0731)			Moderately slow 0.0584 (0.1263)	Moderately unsupportive 0.0584 (0.1263)	Moderately unsupportive 0.0584 (0.1263)
			Slow 0.0299 (0.0647)	Very unsupportive 0.0299 (0.0647)	Very unsupportive 0.0299 (0.0647)

Table 13. Rating Importance of Benefits, Opportunities, Costs and Risks

	Financial	**Availability of experts**	**Flexibility**	**Time–to-market**	**Media perception**	**Shareholder & employee perception**	**Priorities**
Benefits	High possibility to reduce costs	Immediately	Hi	Fast	Moderately unsupportive	Moderately unsupportive	**0.2985**
Opportunities	High possibility to reduce costs	Immediately	Hi	Fast	Moderately unsupportive	Moderately unsupportive	**0.2985**
Costs	Somewhat unlikely to reduce	Moderately	Med	Average	Moderately supportive	Moderately supportive	**0.1045**
Risks	High possibility to reduce costs	Immediately	Hi	Fast	Moderately unsupportive	Moderately unsupportive	**0.2985**

4. RESULTS

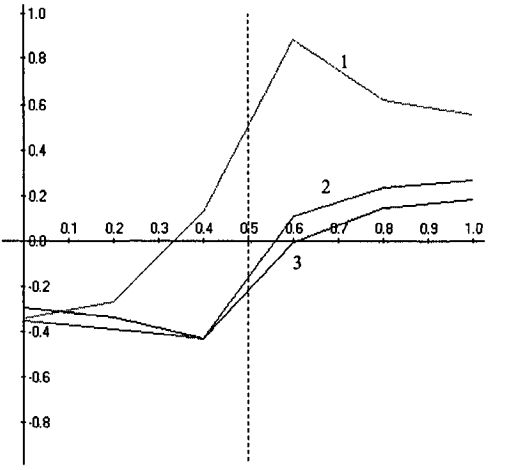
After pairwise comparisons of the alternatives and ratings comparisons of the merits, our model shows that Alternative #1: "Outsource all application development work", is the best choice (see Table 14). The main driver for this result is the financial benefits. Using background research and personal interviews to describe this model and compare and rate its nodes, the authors of this chapter are not surprised by this outcome.

Table 14. Overall Outcome

Alternatives	Benefits 0.2983	Opportunities 0.2983	Costs 0.1051	Risks 0.2983	Outcome BO/CR	Outcome bB + oO – cC - rR
1	1	1	0.8313	1	1.2029	0.2109
2	0.3972	0.8277	0.7468	1	0.4402	-0.0114
3	0.1776	0.4908	0.9759	0.3570	0.2502	-0.0097

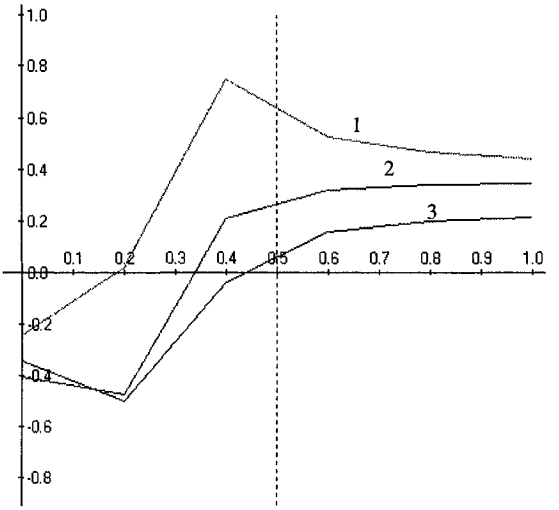
1 - Outsource all application development work
2 - Outsource the design and programming phases
3 - Do not outsource any application development work

5. SENSITIVITY ANALYSIS



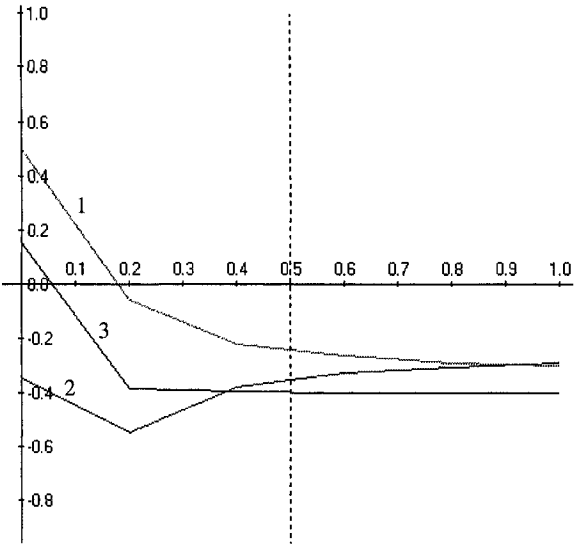
1 – Outsource all application development work
2 – Outsource the design and programming phases
3 – Do not outsource any application development work

Figure 15. Sensitivity Analysis for Benefits



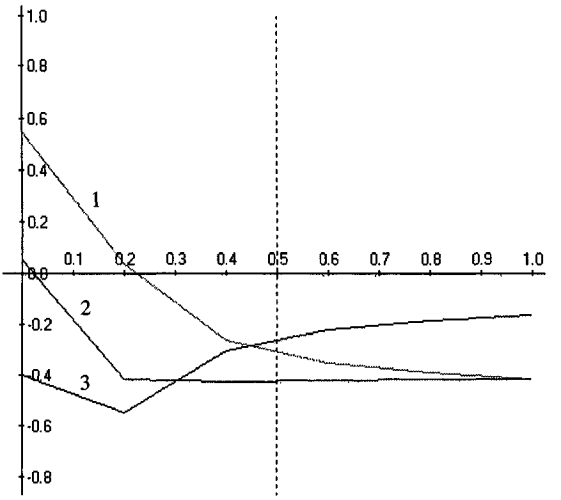
1 – Outsource all application development work
2 – Outsource the design and programming phases
3 – Do not outsource any application development work

Figure 16. Sensitivity Analysis for Opportunities



1 – Outsource all application development work
2 – Outsource the design and programming phases
3 – Do not outsource any application development work

Figure 17. Sensitivity Analysis for Costs



1 – Outsource all application development work
2 – Outsource the design and programming phases
3 – Do not outsource any application development work

Figure 18. Sensitivity Analysis for Risks

6. WHERE TO OUTSOURCE

A separate study was made by Ozlem Arisoy and Shengnan Wu in the Fall of 2005 for a company in Pennsylvania to determine the best country where to outsource. The results of that study are given in Tables 15-17 below. It suggests that Taiwan should be the outsourcing location.

By way of validation, it was announced in December 2005 that Taiwan's Quanta, the world's largest maker of notebook computers, was selected to manufacture an ultra-low-cost laptop developed by Nicholas Negroponte, the chairman of the Massachusetts Institute of Technology's Media Laboratory.

Table 15. Benefits and Opportunities Priorities

Benefits	Economic	Organization	Production	
Control Criterion (CC)	Limiting CC	Limiting CC	Limiting CC	
Normalized →	0.6483	0.1220	0.2297	
Alternatives ↓	Ideal	Ideal	Ideal	Synthesis
Mainland China	0.9538	0.3526	0.3310	0.7374
Taiwan	1.0000	1.0000	0.5798	0.9035
Hong Kong	0.7424	0.9005	0.7665	0.7672
Japan	0.5319	0.3509	1.0000	0.6173
India	0.4166	0.2754	0.1915	0.3477

Opportunities	Global Long Term	Global Short Term	Local Long Term	Local Short Term	
Control Criterion (CC)	Limiting CC	Limiting CC	Limiting CC	Limiting CC	
Normalized →	0.3216	0.3341	0.2232	0.1211	
Alternatives ↓	Ideal	Ideal	Ideal	Ideal	Synthesis
Mainland China	1.0000	1.0000	1.0000	1.0000	1.0000
Taiwan	0.5606	0.5940	0.6119	0.3616	0.5591
Hong Kong	0.5537	0.3098	0.4628	0.2882	0.4198
Japan	0.5201	0.4075	0.8361	0.2891	0.5250
India	0.5066	0.2370	0.3748	0.4545	0.3808

Table 16. Costs and Risks Priorities

Costs	Manufacturing	Marketing	Implementation	
Control Criterion (CC)	Limiting CC	Limiting CC	Limiting CC	
Normalized →	0.2790	0.6491	0.0719	
Alternatives ↓	Ideal	Ideal	Ideal	Synthesis
Mainland China	0.1527	0.2647	0.3931	0.2427
Taiwan	0.3835	0.4165	0.4926	0.4128
Hong Kong	0.6172	0.7043	0.7169	0.6809
Japan	1.0000	1.0000	1.0000	1.0000
India	0.1409	0.2422	0.3138	0.2191

Risks	Operations	Implementation	Performance	
Control Criterion (CC)	Limiting CC	Limiting CC	Limiting CC	
Normalized →	0.1365	0.6250	0.2385	
Alternatives ↓	Ideal	Ideal	Ideal	Synthesis
Mainland China	1.0000	1.0000	1.0000	1.0000
Taiwan	0.3634	0.5353	0.3966	0.4788
Hong Kong	0.2052	0.4604	0.5609	0.4495
Japan	0.1168	0.4559	0.1596	0.3389
India	0.6376	0.9480	0.9403	0.9038

Table 17. Priorities of the Alternatives from BOCR Models and Synthesis

	Benefits	Opportunities	Costs	Risks	Synthesis
Alternatives	0.2050	0.2046	0.2046	0.3858	**bB+oO-cC-rR**
Mainland China	0.7374	1.0000	0.2427	1.0000	-0.0797
Taiwan	0.9035	0.5591	0.4128	0.4788	0.0305
Hong Kong	0.7672	0.4198	0.6809	0.4495	-0.0696
Japan	0.6173	0.5250	1.0000	0.3389	-0.1014
India	0.3477	0.3808	0.2191	0.9038	-0.2443

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CHAPTER 5

ANWR - ARTIC NATIONAL WILDLIFE REFUGE: AN ANP VALIDATION EXAMPLE

Justin Emanuel and Pete Cefalu
(Fall 2002)

1. INTRODUCTION

ANWR-Arctic National Wildlife Refuge covers 19 million acres on the Northern coast of Alaska. The entire refuge lies north of the Arctic Circle and 1,300 miles south of the North Pole. The Coastal Plain area comprising 1.5 million acres on the northern edge of ANWR, is bordered on the north by the Beaufort Sea, on the east by the U.S. Canadian border and on the west by the Canning River. The consensus of the geologic community is that the Coastal Plain of ANWR represents the highest petroleum potential onshore area yet to be explored in North America. If explored, it is estimated that it will take 15 years or more before oil and gas will reach the market.

President Eisenhower originally protected this coastal plain area, also known as area 1002, in 1960. Twenty years later President Carter signed the Alaska National Interest Conservation Act. This legislation was important as it created a majority of the National Parks in Alaska and expanded ANWR to its current size. A compromise was reached to pass the legislation, in return for designating a majority of the area-protected land. Area 1002 was left unprotected and thus open for exploration.

Each administration since has had its own opinion regarding the land and what should be done with it. The Reagan Administration was ready to drill but was derailed by the Exxon Valdez catastrophe. The first Bush Administration likewise was unsuccessful. The Clinton Administration designated the area for protection and it has been since.

The second Bush Administration, in response to ongoing Middle East violence and recent terrorist attacks, namely 9/11, sees drilling in ANWR as vital not only for economic but national security reasons. Several environmental groups consider ANWR a great American natural treasure and one of the last places on the earth where an intact expanse of arctic and sub-arctic lands remain protected. They feel the habitat, the wildlife, and the culture need to be protected from the exploration of gas and oil.

An ANP model (Figure 1) was developed as a way of coming to a decision regarding the use of this land. This model incorporates pairwise comparisons of benefits, opportunities, costs, and risks associated with drilling or not drilling. By making these comparisons and choosing the answers that best represent the use of this land we were able to come to a plausible conclusion on whether or not the land should be further explored.

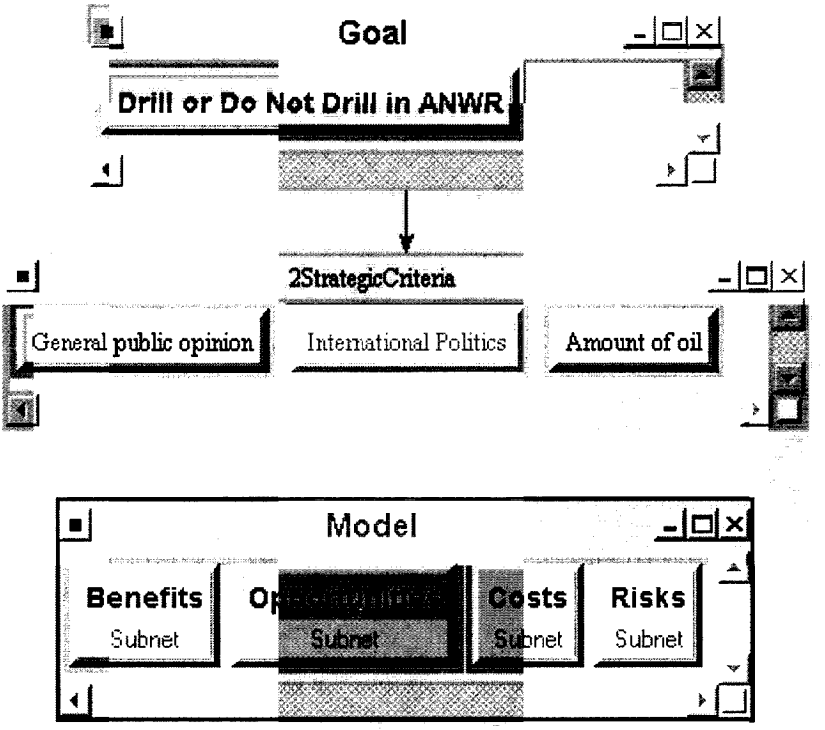

Figure 1. BOCR Model

2. BOCR MODEL FOR ANWR

The ANWR Model depicted in Figure 1 considers strategic criteria used to evaluate the benefits, opportunities, costs and risks of the alternatives Drill/Do Not Drill for Oil. These criteria are:

- **General public opinion:** Local, national and international public opinion.
- **International Politics:** The implications of the Drill/Do Not Drill decision on the relations with OPEC nations.
- **Amount of oil:** The quantity of oil that is available in the ANWR area. For example, if the amount of oil in ANWR is very low, one would expect that the outcome of this criterion would lean towards the Do Not Drill for oil decision.

The structure of the benefits, opportunities, costs and risks subnets are given in Figures 2 to 5. The meaning of the control criteria, in each of the subnets, is given below.

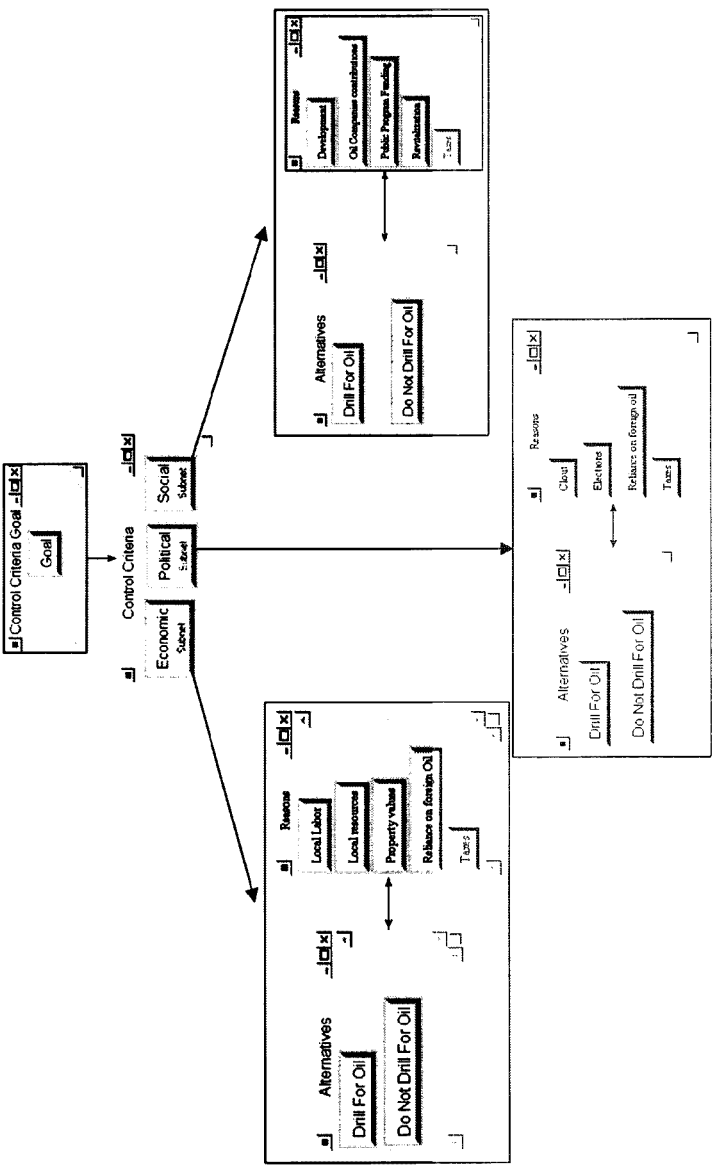

Figure 2. Benefits Subnet

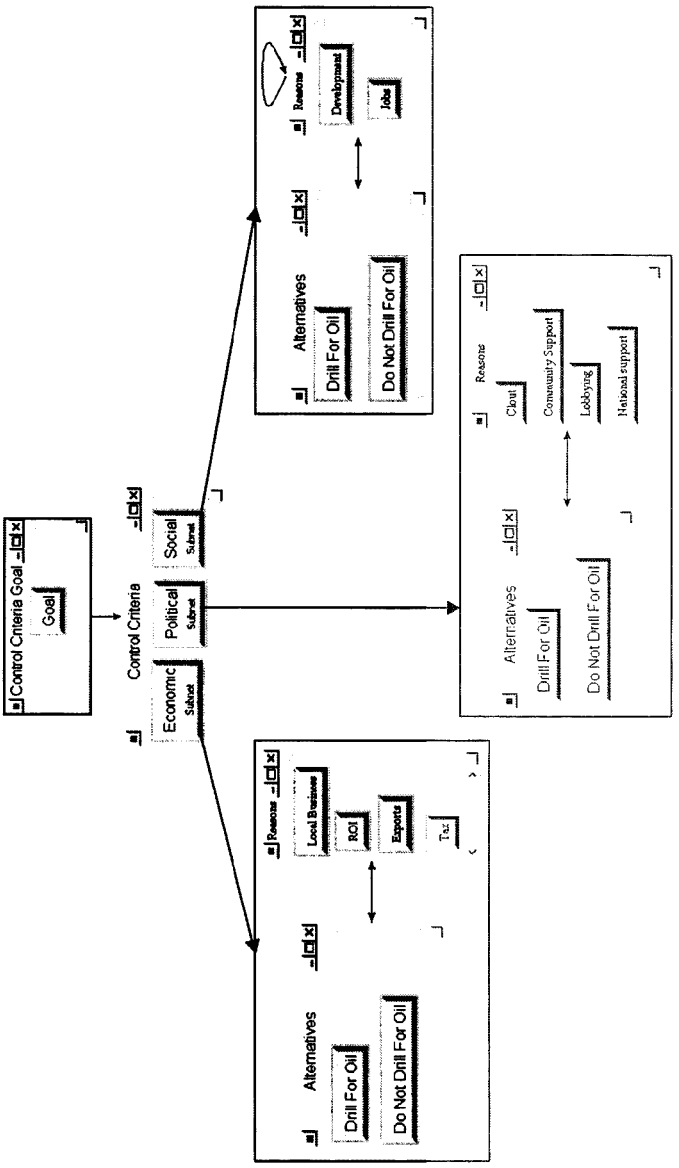

Figure 3. Opportunities Subnet

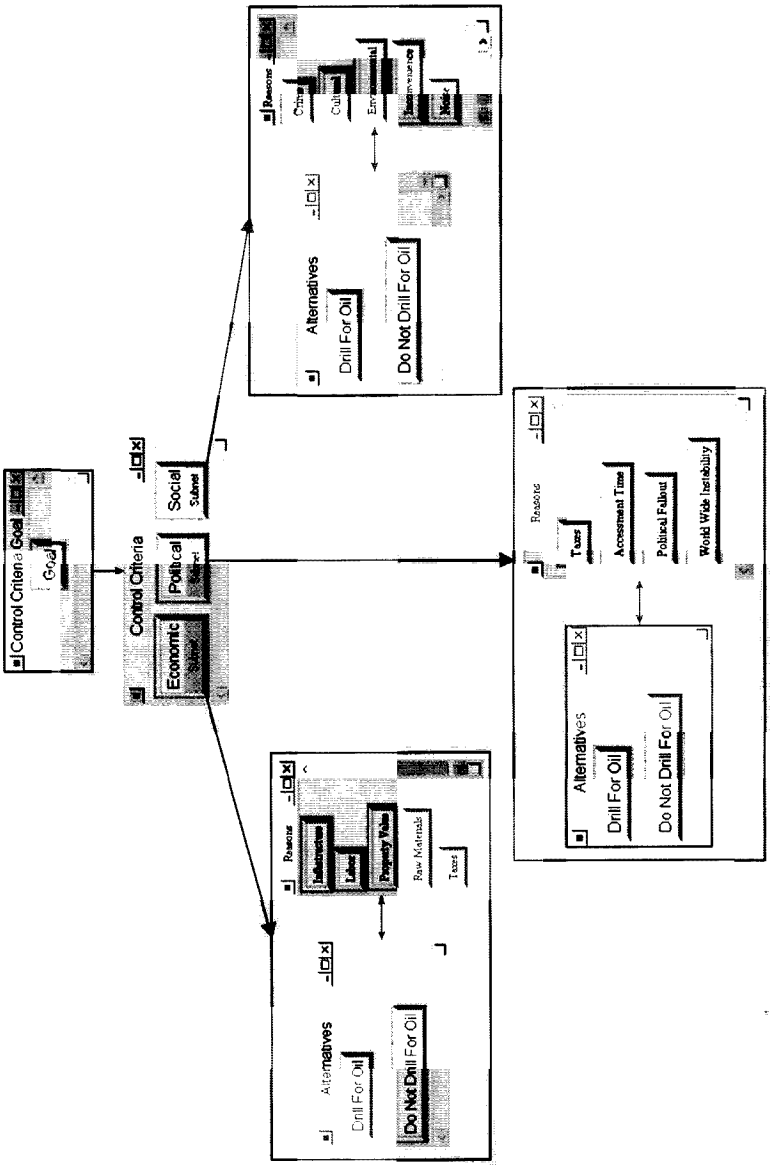

Figure 4. Costs Subnet

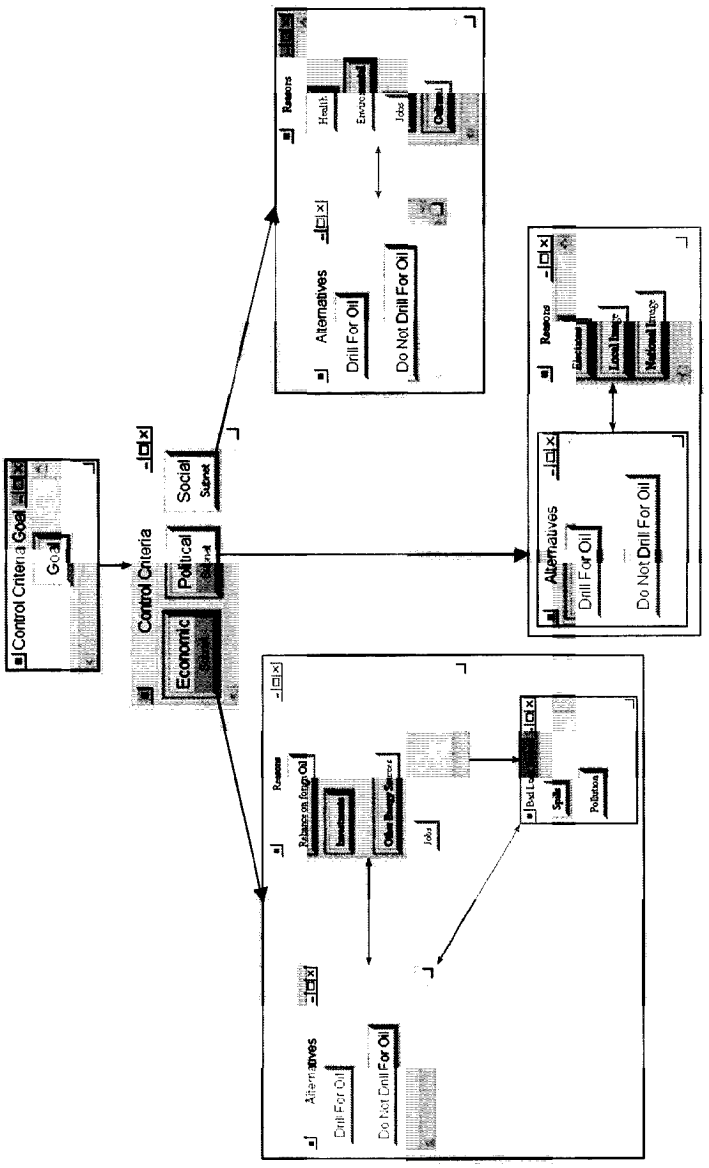

Figure 5. Risks Subnet

The benefits, opportunities, costs and risks are divided into economic, political and social.

(1) Benefits Network

Benefits/Economic criteria

- **Local Labor:** Local work force and Local Jobs
- **Local resources:** Use of local raw materials that would boost other local industries in Alaska
- **Property values:** The effects of ANWR on the nearby property values
- **Reliance on Foreign Oil:** Whether or not the US would be able to use its own oil instead of relying on the Middle East and other nations
- **Taxes:** What effect would this have on taxes

Benefits/Political criteria

- **Clout:** Political Power resulting from drilling or not drilling for oil
- **Elections:** The effect drilling or not drilling would have on democratic and republican elections
- **Reliance on foreign oil:** How drilling or not drilling would affect the US and the use of foreign oil.
- **Taxes:** What would the effect be on taxes?

Benefits/Social criteria

- **Development:** Development of socialization locally
- **Oil Companies contributions:** Effect of oil companies contributing funds
- **Public Program Funding:** Public funding provided to help residents succeed
- **Revitalization:** re-stimulate the local social atmosphere
- **Taxes:** Effect on taxes

(2) Opportunities network

Opportunities/Economic criteria

- **Exports:** Value of exports
- **Local Business:** Use of local businesses
- **ROI:** Return on investment
- **Tax:** New tax rate

Opportunities/Political criteria

- **Clout:** Political power
- **Community Support:** Support received locally
- **Lobbying:** Lobbying for votes
- **National support:** Support received nationally

. Opportunities/Social criteria

- **Development:** Development of surrounding areas
- **Jobs:** Jobs created locally

(3) Costs network

Costs/Economic criteria

- **Infrastructure:** Cost of roads and railways to access the area

- **Labor:** Cost of labor needed to build and run new facility
- **Property Value:** What will happen to property value of nearby residents and businesses
- **Raw Materials:** Cost of raw materials needed

Costs/Political criteria

- **Assessment Time:** The time it takes to access the situation
- **Political Fallout:** What will cause political fallout
- **Taxes:** What is the cost of new taxes
- **World Wide Instability:** cost of causing world wide stability

Costs/Social criteria

- **Crime:** Crime rate
- **Cultural:** Historical cultural issues
- **Environmental:** effects on the environment
- **Inconvenience:** Inconvenience to inhabitants
- **Noise:** Noise pollution

(4) Risks network

Risks/Economic criteria

- **Bad Luck Events:**
  - **Pollution:** Pollution created
  - **Spills:** Oil Spills
- **Reasons:** Description
  - **Investments:** Investing in US companies
  - **Jobs:** Jobs created
  - **Other Energy Sources:** Wind, solar, gas, etc.

  Reliance on Foreign Oil: US oil Vs. Foreign oil

Risks/Political criteria

- **Elections:** Election outcomes
- **Local Image:** Local image created
- **National Image:** Portrayed national image

Risks/Social criteria

- **Cultural:** Cultural effects
- **Environmental:** Effects on environment
- **Health:** Effects on health

  Jobs: Jobs created

3. RESULTS

Table 1 shows the priorities of the criteria for the economic, political and social benefits, opportunities, costs and risks networks.

Table 1. Priorities from Benefits, Opportunities, Costs and Risks Subnets and from BOCR Ratings

		Criteria	Priorities
Benefits	Economic	**Local Labor**	0.2248
1.0000	0.6910	**Local Resources**	0.0984
(0.4252)		**Property Values**	0.1784
		Reliance on Foreing Oil	0.4353
		Taxes	0.0630
	Political	**Clout**	0.1051
	0.2176	**Elections**	0.3255
		Reliance on Foreign oil	0.4530
		Taxes	0.1164
	Social	**Development**	0.3010
	0.0914	**Oil Companies Contributions**	0.0649
		Public Program Funding	0.1057
		Revitalization	0.3403
		Taxes	0.1881
Opportunities	Economic	**Exports**	0.1375
0.8940	0.2790	**Local Business**	0.6124
(0.3801)		**ROI**	0.1490
		Tax	0.1011
	Political	**Clout**	0.2619
	0.0719	**Community Support**	0.4315
		Lobbying	0.1804
		National support	0.1263
	Social	**Development**	0.4165
	0.6491	**Jobs**	0.5835
Costs	Economic	**Infrastructure**	0.1519
0.1102	0.6491	**Labor**	0.4853
(0.0469)		**Property Value**	0.1271
		Raw Materials	0.1655
		Taxes	0.0702
	Political	**Assessment Time**	0.2123
	0.0719	**Political Fallout**	0.6127
		Taxes	0.0929
		World Wide Instability	0.0822
	Social	**Crime**	0.3096
	0.2790	**Cultural**	0.1982
		Environmental	0.1795
		Inconvenience	0.1107
		Noise	0.2020
Risks	Economic	**Pollution**	0.3948
0.3478	0.1939	**Spills**	0.6052
(0.1479)		**Investments**	0.1126
		Jobs	0.2151
		Other Energy Sources	0.5587
		Reliance on Foreign Oil	0.1136
	Political	**Elections**	0.3875
	0.0633	**Local Image**	0.4253
		National Image	0.1872
	Social	**Cultural**	0.1171
	0.7429	**Environmental**	0.3706
		Health	0.2232
		Jobs	0.2891

Table 2 gives the priorities of the alternatives Drill/Do Not Drill for the benefits, opportunities, costs and risks.

Table 2. Priorities of Alternatives from BOCR Models

	Economic	Political	Social	
Benefits	0.6910	0.2176	0.0914	Synthesis
Drill	1.0000	1.0000	1.0000	**1.0000**
Do Not Drill	0.3073	0.4537	0.2900	**0.3376**

	Economic	Political	Social	
Opportunities	0.2790	0.0719	0.6491	Synthesis
Drill	1.0000	1.0000	1.0000	**1.0000**
Do Not Drill	0.1647	0.3557	0.1940	**0.1975**

	Economic	Political	Social	
Costs	0.6491	0.0719	0.2790	Synthesis
Drill	1.0000	1.0000	1.0000	**1.0000**
Do Not Drill	0.1721	0.1656	0.6760	**0.3122**

	Economic	Political	Social	
Risks	0.1939	0.0633	0.7429	Synthesis
Drill	0.4978	0.7941	0.5461	**0.5524**
Do Not Drill	1.0000	1.0000	1.0000	**1.0000**

Benefits, opportunities, costs and risks are now rated using the three strategic criteria depicted in Figure 1, according to the best alternative under each of the BOCR models. The results are given in Table 3.

Table 3. BOCR Ratings

	General Public Opinion 0.1007	**International Politics** 0.2255	**Amount of Oil** 0.6738	Total	**Priorities**
Benefits	High (1.0000)	Medium (0.3770)	High (1.0000)	0.8595	**0.4252**
Opportunities	Low (0.0947)	Medium (0.3770)	High (1.0000)	0.7684	**0.3801**
Costs	Low (0.0947)	Low (0.0947)	Low (0.0947)	0.0947	**0.0469**
Risks	Low (0.0947)	High (1.0000)	Low (0.0947)	0.2989	**0.1479**

Intensities: High 1.0000 Medium 0.3770 Low 0.0947

Finally, the priorities of the BOCR models are used to synthesize the individual priorities of the alternatives under each model. Table 4 gives the results from the additive probabilistic (predictive) synthesis.

Table 4. BOCR Synthesis

	Benefits	Opportunities	Costs	Risks	bB+oO+c(1-C)+r(1-R)	
	0.4252	0.3801	0.0469	0.1479	Total	Normalized
Drill	1.0000	1.0000	1.0000	0.5524	0.8715	0.7765
Do Not Drill	0.3376	0.1975	0.3122	1.0000	0.2508	0.2235

4. Conclusion and Sensitivity Analyses

In sum, exploring for oil and gas seems to be a better alternative for ANWR. The model indicates that ANWR should be opened to oil and gas exploration by 77.65%. This result appears to be in agreement with a recent poll of native Alaskans in which they show support for opening ANWR to oil and gas exploration. The question asked was "Do you believe oil and gas exploration should or should not be allowed within the ANWR Coastal Plain?" The poll results are show in Figure 6. The Unsure 6%, divided equally between Should and Should not makes their values 78% and 22% respectively, resulting in nearly identical values to those obtained from the model.

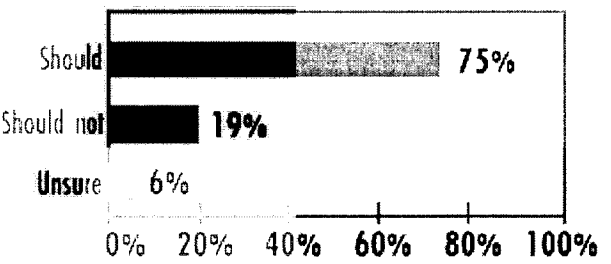

Figure 6. Poll's Results

This outcome is consistent with our findings and it also appears to be with all geographic subgroups in Alaska (See Figure 7).

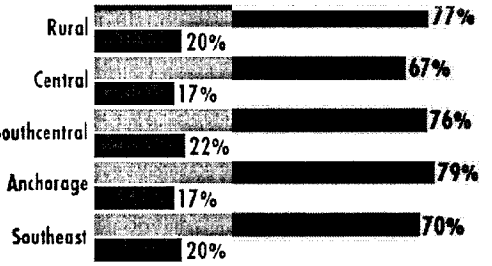

Figure 7. Poll's Results for Geographical Subgroups

The decision to Drill is dominant and stable under benefits, opportunities and risks. Only under costs Drill and Do Not Drill change rankings. If the priority of costs is below 40 percent, the decision to Drill dominates. When the priority of costs is above 40 percent, the Do Not Drill decision is preferred (see Figure 8).

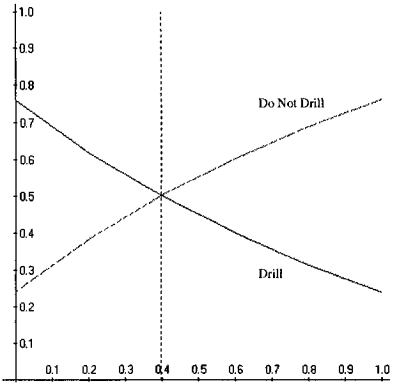

Figure 8. Sensitivity Analysis of the Alternatives Under Costs

Combining benefits, opportunities, costs and risks, the Drill decision dominates in almost the entire spectrum with very few exceptions characterized by high priorities in costs and risks combined. Figure 9 shows the fluctuations in the priorities of the alternatives as the weights of the BOCR models change.

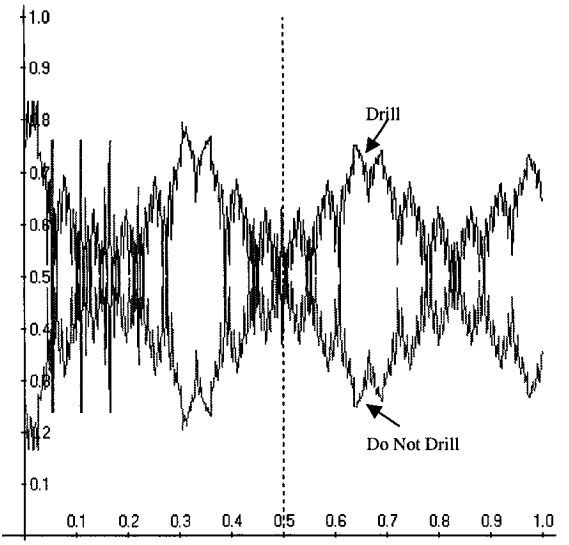

Figure 9. Sensitivity Analysis of the Alternatives Under All BOCR Models

CHAPTER 6

THE FORD EXPLORER CASE

Juan P. Alberio and Suri Mulani
(Winter 2001)

1. INTRODUCTION

In August 9, 2000 the companies Firestone and Ford announced a recall[1] of 6.5 million tires that contained a safety-related defect. The recall was the result of an abnormal high rate of treads separations that caused catastrophic rollover crashes[2] which maimed and killed drivers and passengers. At that time, the companies' had jointly decides that Decatur was the appropriate focus for a recall of Wilderness AT tires, thus excluding millions of identical tires made in Firestone's Wilson, North Carolina and Joilette, Quebec, Canada plants.

The tires had been sold as original equipment on Ford's Explorer SUV, and manufactured according to specifications from Ford.

Ford announced in March 2001 that the company would redesign the Explorer model (creating the new Explorer) adding a wider body and incorporating some "rollover" features.

In May 2001, the Ford Motor Company also announced a new recall of 13 million tires from the Ford Explorer models and termination of the business relationship with Firestone.

There are several key players in the tire separation tread case. The first is the company that designed and manufactured the tires: Firestone. The second is the company that designed and manufactured the vehicles: Ford Motor Company. The third is the governmental regulation agency: the National Highway Safety Administration (NHTSA).

2. CREATING THE MODEL

The model for finding the optimal decision for Ford regarding the Explorer/Firestone conflict was designed using a benefits, costs, and risks model. The benefits model would indicate the decision that gives the most benefits, whereas the costs and risks models indicate the decisions that are most costly and risky. Using the ANP program *SuperDecisions*, the calculation of the formula is done automatically.

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[1] The recall included all 15-inch ATX II tires and those 15-inch Wilderness AT tires manufactured by Firestone plant in Decatur, Illinois.
[2] 148 deaths and 525 injuries by the end of year 2000

Alternatives

Discontinue Explorer production: Ford would stop the Explorer model production.

Redesign the Explorer model: Ford would continue producing the Explorer model but the company would redesign some parts of the Sport Utility Vehicles (SUV) in order to increase the safety level of the vehicle.

Maintain the production of Explorer Model: Ford would keep on producing the Explorer model without any modifications.

Maintain the production of Explorer Model, but change the tire supplier: Ford would keep on producing and commercializing the current Explorer model equipped with tires from a different supplier.

Cluster Definitions

Under the benefits, costs, and risks models, there are different clusters defined that interact with respect to the control hierarchy established. For benefits and risks, the control hierarchy consists of social and economic factors; while the costs control hierarchy includes social, economic, and political factors. Although the clusters and the specific elements assigned to each network vary due to their interactions, the following general definitions apply to all.

a. Alternative Decisions

The alternative decisions cluster includes the potential decisions for the Ford Motor Company regarding the Ford/Firestone conflict. The potential decisions included are:

- Discontinue Explorer production.
- Redesign the Explorer model.
- Maintain the production of Explorer Model.
- Maintain the production of Explorer Model, but change the tire supplier.

b. Stakeholders

The stakeholders include people or groups that would be impacted by the alternative decisions made by Ford. The elements in this cluster are the following:

- Customers: current and potential buyers
- Community: people who may not be a customer but could be affected by the alternative decisions
- Employees: Ford Motor Company employees, including labor and management
- Nation's Highway Safety Agency: government agency

c. Tire Suppliers

This cluster considers current and potential tire suppliers for Ford. The elements in this cluster are the following: Firestone, Goodyear, Michelin, and Other Tire Suppliers.

d. Competition

The competition cluster includes other SUV brands and models owned by Ford and other companies. The elements in this cluster are the following:

- Ford's other SUV brands (e.g. Escape)
- Ford affiliates' SUV brands (e.g. Land Rover)
- Other companies' SUV brands (e.g. GM, Honda, Lexus, Dodge, etc)

e. Public Relation

This cluster considers elements that would impact the company's relationships with the stakeholders. The elements in this cluster are the following:

- Image : the company's image in public
- Trust : reliability in the company's name
- Accountability : how the company react to community threats caused by Ford Motor Company's products
- Legal Matters : current and potential lawsuits filed against the company

f. Brand Image

The Brand Image cluster describes major aspects of the products that would impact the company's image. The elements in this cluster are the following: Quality, Safety, Prestige, and Service.

g. Cost of Resources

The cost of resources refers to those costs that Ford may incur when choosing the alternative decisions. The elements in this cluster are the following:

- Layoff costs: the cost that the company would incur in case it decides to reduce the number of employees.
- Launching costs: the cost that the company would incur in case they decide to launch a new product.
- Write-off costs: the cost that the company would incur in case they decide to reduce the inventory of discontinued products.
- Production costs: the cost that the company incurs during the production stage

h. Resources

The Resources cluster includes: Revenues, Production Capacity, and Market Share.

Procedure

The benefits, costs and risks in the decision that Ford would have to make regarding the Ford Explorer Model, were rated on three criteria: Domestic Issues, International Relations and Human Well-Being. In Domestic Issues, the sub criteria were: a) Ford's reputation, b) Car Industry's reputation and c) US Government's reputation. In the case of International Relations, the sub criteria were: a) Relationship with customers in other countries, b) Relationship with suppliers in other countries and c) Relationship with other countries' governments. Finally, in the case of Human Well-Being, the sub criteria were: a) Future Safety Factors, b) Confidence in government agencies and c) Confidence in the Justice system.

3. BENEFITS MODEL

Frequently, the alternatives from which a choice must be made in a decision-making situation have both benefits and costs associated with them. This is the case for the Ford Motor Company decision. Generally, benefits, costs and risks cannot be combined; they are opposing forces. Thus, in our model, it is useful to construct separate benefits, costs and risks networks, with the same decision alternatives located on each.

Benefits in our model are gains and advantages from making a given decision, partitioned into two categories: economic and social. Economic benefits refer to a decision's positive effect on stakeholders, tire suppliers, competition and resources. Last, social benefits describe a decision's positive effect on stakeholders, tire suppliers, competition and resources.

Economic Benefits Clusters, Links and Judgments

Table 1 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters are shown in Figures 1 and 2.

The 'stakeholders' cluster, obviously, refers to the people or group of people who could potentially benefit economically, based on different decision alternatives taken by Ford. This cluster also affects the 'competition' cluster, because the decisions made may drive the stakeholder to provide economic benefits to either one of the competitors. The 'stakeholders' cluster also affects the 'resources' cluster. The 'resources' cluster refers to the internal resources that the company has. For example, the company's revenue would be impacted by some of the actions taken by the stakeholders.

Table 1. Economic benefits cluster and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Tires Suppliers	Firestone, Goodyear, Michelin and Other tire suppliers.
Competition	▪ Ford's other SUV brands ▪ Ford affiliates' SUV brands ▪ Other companies' SUV brands
Public Image	Image, Trust, Accountability and Legal matters.
Resources	Revenue, Production Capacity and Market Share.

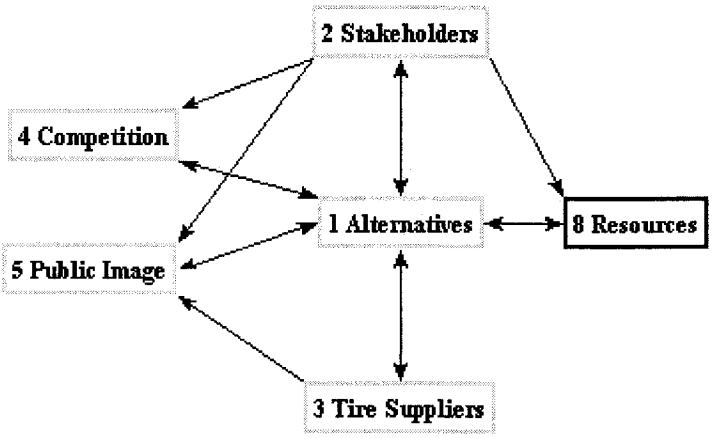


Figure 1. Macro View of Economic Benefits Networks

The 'tire suppliers' cluster refers to tire companies that may gain economic benefits based on the decision alternatives taken by Ford. This cluster would also affect the 'public image' cluster; more specifically, legal matters.

The 'stakeholders' and 'tire suppliers' clusters have more inter-links than the other clusters. This is due to the nature of the network, economic benefits, which usually has more impact on a person or a group of persons. In this network, there is no inter-dependence in any of the clusters.

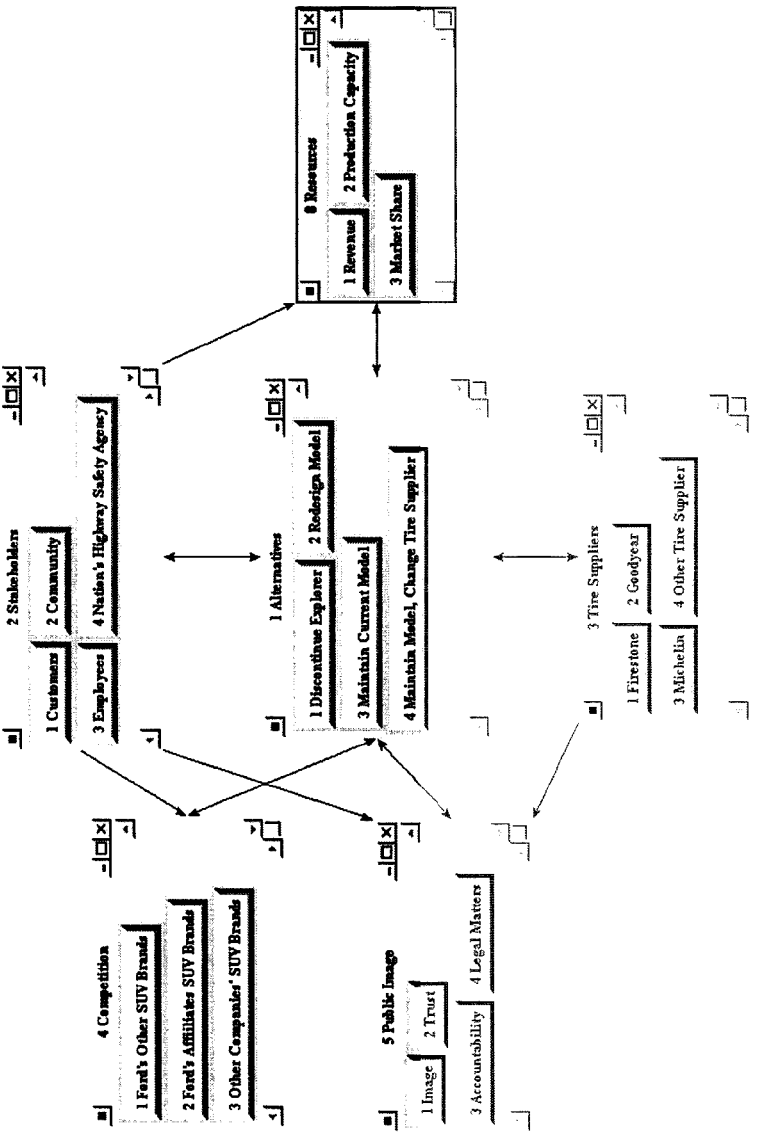


Figure 2. Micro View of Economic Benefits Network

Social Benefits Clusters, Links and Judgments

Table 2 illustrates the clusters in this network and their respective elements:

Table 3. Social benefits clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Tires Suppliers	Firestone, Goodyear, Michelin and Other tire suppliers.
Competition	▪ Ford's other SUV brands ▪ Ford affiliates' SUV brands ▪ Other companies' SUV brands
Public Image	Image, Trust, Accountability and Legal matters.
Brand Image	Quality, Safety, Prestige, and Service

The inner and outer dependencies of clusters in the Social Benefits model are shown in Figures 3 and 4.

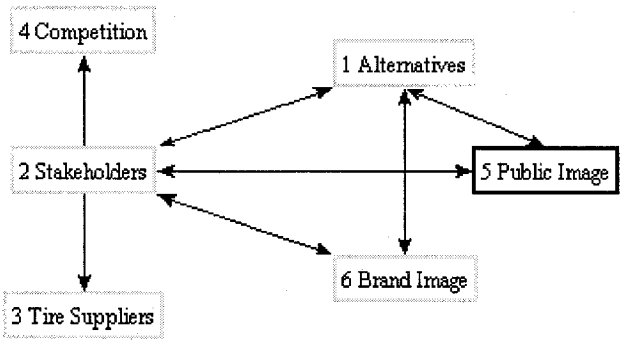


Figure 3. Macro View of Social Benefits Networks

The 'stakeholders' cluster, refers to the people or group of people who could potentially benefit socially, based on different decision alternatives taken by Ford. There is a link between this cluster and the 'tire suppliers' cluster. However, this link only reflects an equal importance to the nodes in the 'tire suppliers' cluster. From the stakeholder's point of view, there are no social benefits in choosing one tire supplier over the other.

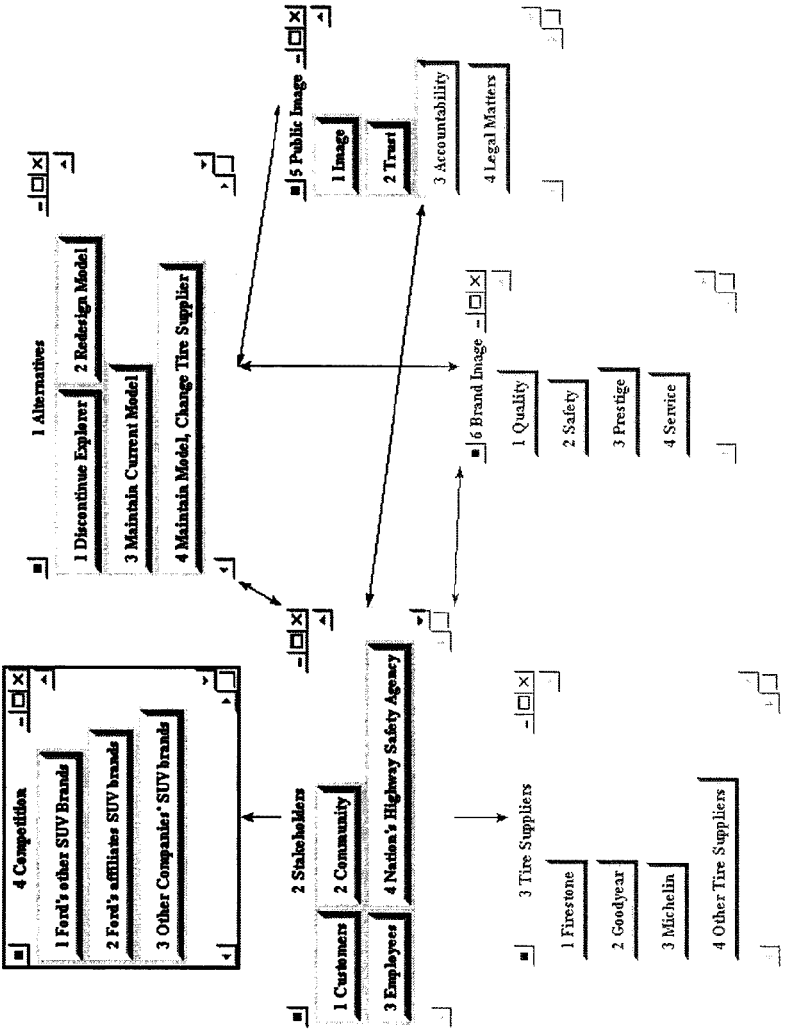


Figure 4. Micro View of Social Benefits Network

The 'stakeholders' cluster also affects the 'competition' cluster, because the decisions made may drive the stakeholder to provide social benefits to either one of the competitors.

The next cluster that is affected is the 'public image' cluster. The stakeholders can provide social benefits based on the alternative decisions taken by Ford, and that would impact how they see the company's public image in terms of trust, image, accountability, and legal matters.

The last cluster that is impacted is the 'brand image' itself. This requires no further explanation, as the alternative decisions taken would clearly have the power to change how stakeholders perceive the brand's image. Different stakeholder may value different brand images, but overall, this cluster would be very much influenced by the stakeholders.

The 'stakeholders' cluster plays an important role in this network, and as in the Economic Benefits network, there is no inter-dependence in any of the clusters in the Social Benefits network.

Synthesis of Judgments in the Benefits Model

Both networks in the benefits have independent results that would then feed into the higher-level network (the overall benefits network). The combined results from the Economic and Social Benefits networks are shown in Table 4.

This result indicates that from the Benefits point of view, the alternative decision of discontinuing Explorer gives the highest benefit, both from the economic and social standpoints.

Table 4. Synthesized Judgments in the Benefits Model

	Benefits		
	Economic	Social	
Alternatives	0.8	0.2	Synthesis
Discontinue Explorer	1.0000	1.0000	1.0000
Redesign Model	0.3699	0.5929	0.4145
Maintain Current Model	0.1241	0.0194	0.1031
Maintain Model, Change Tire Supplier	0.5869	0.2145	0.5124

Another observation is that the overall priority for the first ranked alternative, i.e. to discontinue Explorer, has a significantly larger value than the next alternative. As seen from the table, the alternative 'Discontinue Explorer' is the best under both Economic and Social benefits, while the second best alternative, i.e. 'maintain model, change tire supplier', only has 0.5124 priority. The ratio is almost twice as much, which shows how important the first ranked alternative is compared to the other alternatives.

4. COSTS MODEL

The costs to Ford for choosing one alternative over the others can be divided into economic, social and political costs, which comprise the control hierarchy for this model. Economic costs are costs to which a monetary value can be assigned such as production and advertising costs involved in the redesign of the Ford Explorer. Social costs are defined as the expense to society in terms of stakeholder exposure to decisions made regarding the Ford Explorer. Finally, political costs can be defined as the intangible costs due to the decision taken, such as breaking the relationship between Ford and its tire supplier.

Economic Costs Clusters, Links and Judgments

Table 5 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters in the economic costs model are shown in Figures 5 and 6. The 'stakeholders' cluster refers to the people or group of people who could potentially be affected economically, based on different decision alternatives taken by Ford. This cluster also affects the 'public image' cluster, more specifically, 'legal matters'. The decision made by the company may encourage customers to influence the economic costs by increasing the number of lawsuits filed against the company.

Table 5. Economic costs clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Tires Suppliers	Firestone, Goodyear, Michelin and Other tire suppliers.
Competition	▪ Ford's other SUV brands ▪ Ford affiliates' SUV brands ▪ Other companies' SUV brands
Public Image	Image, Trust, Accountability and Legal matters.
Cost of Resources	Layoff Costs, Launching Costs, Writeoff Costs and Production Costs.
Resources	Revenue, Production Capacity and Market Share.

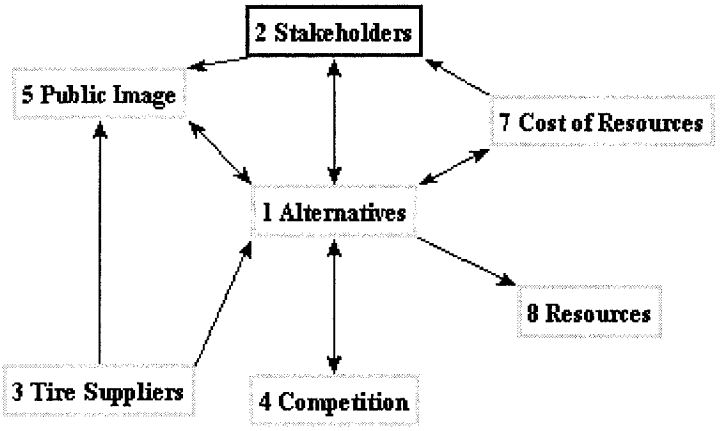


Figure 5. Macro View of Economic Costs Network

The 'tire suppliers' cluster refers to tire companies that may suffer economic costs based on the decision alternatives taken by Ford. This cluster would also affect the 'public image' cluster; more specifically, 'legal matters.' Again, the decision taken by the Ford Company could affect the relationship between Firestone and Ford, increasing the economic costs caused by potential lawsuits filed by Firestone against the company.

The cluster 'cost of resources' refers to the economic costs involved in any potential decision. The rationale used in this cluster is that the decision of laying-off would have a negative economic impact for the company.

The cluster 'resources' refers to the economic cost of making a decision, and basically its impact on the cluster's components such as Revenues, Market Share and Production Capacity. For example, if the company decides to discontinue the Ford Explorer production there would be economic costs such as a decrease in Market Share and in Revenues to the company.

The cluster 'public image' is also affected by the alternatives. This cluster refers to the economic costs that could impact the company such as higher legal costs caused, for example, by the decision of maintaining production of the Explorer Model without any change of tire suppliers.

The cluster 'competition' refers to the economic costs of making a decision related to the competition. For example, if the company decides to discontinue production of the Ford Explorer model, other brands of the Ford Company would also be affected by the decision since customers would perceive the Ford SUV's not as safe as they expected and this could cause additional economic costs.

Figure 6. Micro View of Economic Costs Network

Political Costs Clusters, Links and Judgments

Table 6 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters in this model are shown in Figures 7 and 8.

The 'stakeholders' cluster, refers to the people or group of people who would be negatively affected by decisions made by Ford and that would be defined as political costs. For example, if the company decides to discontinue the model, then there would be additional political costs due to layoffs.

The 'public image' cluster would also be affected by the decision made by Ford. The legal matters would be the most important political costs incurred by the company.

Table 6. Political costs clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Tires Suppliers	Firestone, Goodyear, Michelin and Other tire suppliers.
Public Image	Image, Trust, Accountability and Legal matters.
Cost of Resources	Layoff Costs, Launching Costs, Writeoff Costs and Production Costs.

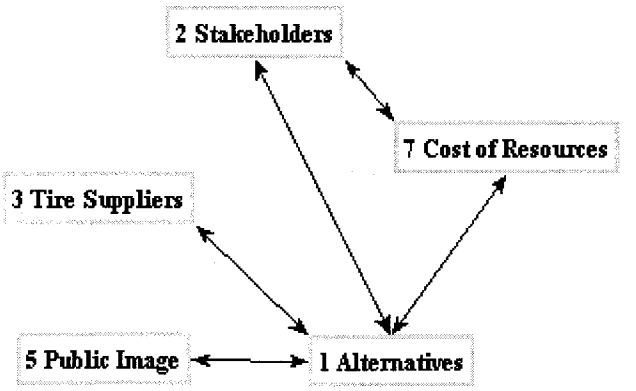


Figure 7. Macro View of Political Costs Network

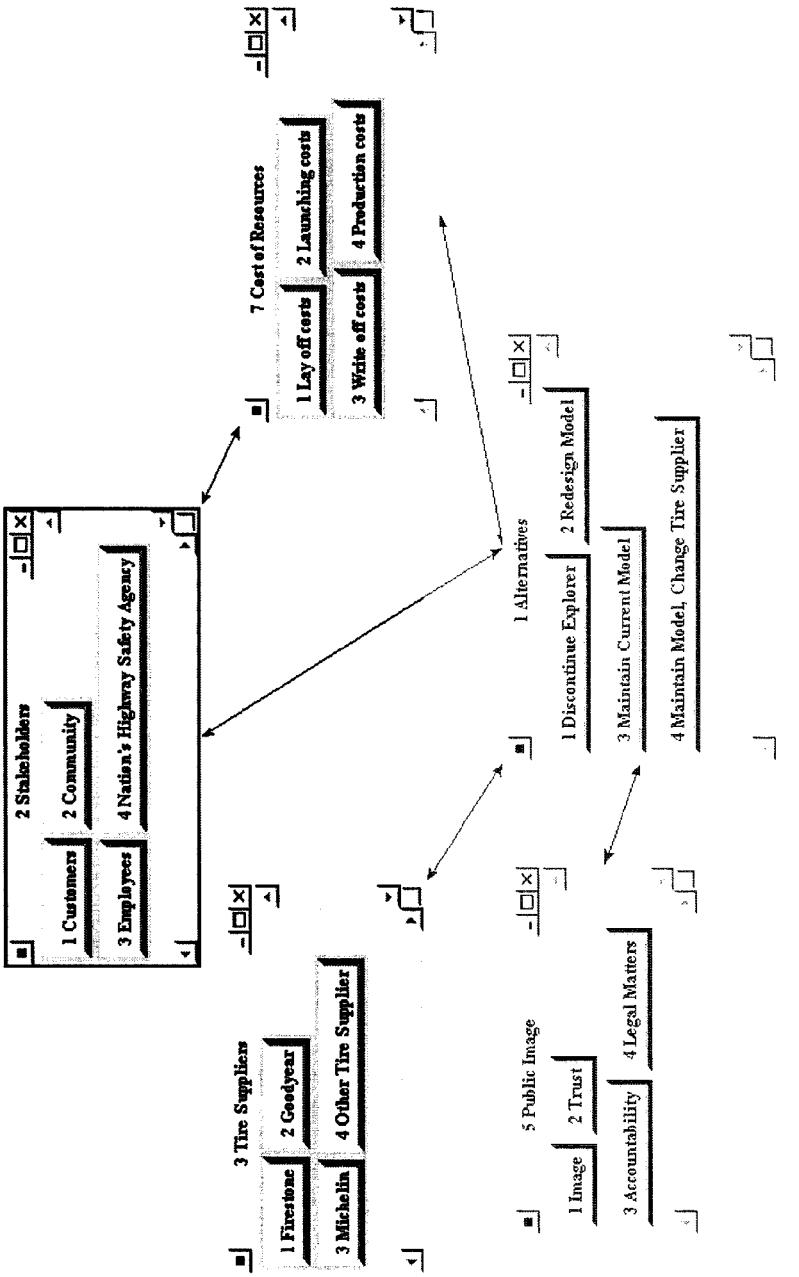


Figure 8. Micro View of Political Costs Network

The 'tire suppliers' cluster refers to the suppliers that could increase the political costs of the company by some of the decisions the company could take. For example, if the company decides to change the tire suppliers, they may incur new political costs with Firestone.

Finally, the cluster 'Cost of resources' refers to the political costs that the company would incur by taking any of the decisions. For example, if the company decides to discontinue the model, then they would probably incur political costs based on the decision of laying-off some of the employees from the Ford Explorer production line.

Social Costs Clusters, Links and Judgments

Table 7 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters in the social costs model are shown in Figures 9 and 10.

The 'stakeholders' cluster, refers to the people or group of people who would incur social costs, based on different decision alternatives taken by Ford. There is a link between this cluster and the 'public image' cluster. This means that, for example, if Ford maintains the Explorer model, then the customers would probably have a social cost, that would affect the Image and Trust in the vehicles from Ford. The same thing would happen between Stakeholders and some components of the 'brand image' cluster.

Table 7. Social costs clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Public Image	Image, Trust, Accountability and Legal matters.
Brand Image	Quality, Safety, Prestige, Service.

The next cluster that is affected is the 'public image' cluster. A bad image of the company as a consequence of a decision could cause social costs for the company in terms of Image and Trust. Again, as previously explained for the case of stakeholders, this cluster is also linked to (and it would affect) brand image and stakeholders.

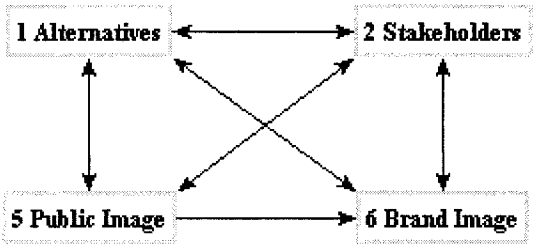


Figure 9. Macro View of Social Costs Network

The last cluster that is impacted is the 'brand image' itself. This requires no further explanation, as the alternative decisions taken would clearly have the power to change how stakeholders perceive the brand's image, with a probable negative impact that we refer to as a social cost for the company.

Synthesis of Judgments in the Costs Model

The combined results from Economic Costs, Political Costs and Social Costs networks can be seen in Table 8.

Table 8. Synthesis of Costs priorities

	Costs			
	Economic	Political	Social	
Alternatives	0.6567	0.0827	0.2606	Synthesis
Discontinue Explorer	0.3825	0.0966	0.0989	0.2592
Redesign Model	1.0000	1.0000	0.0000	0.7394
Maintain Current Model	0.8849	0.3258	0.1264	0.6081
Maintain Model, Change Tire Supplier	0.4701	0.4300	1.0000	0.3443

This result indicates that from the Costs Model point of view, the alternative decision of discontinuing Explorer gives the highest cost to Ford, and the Redesign alternative would have the smallest impact on the company's costs.

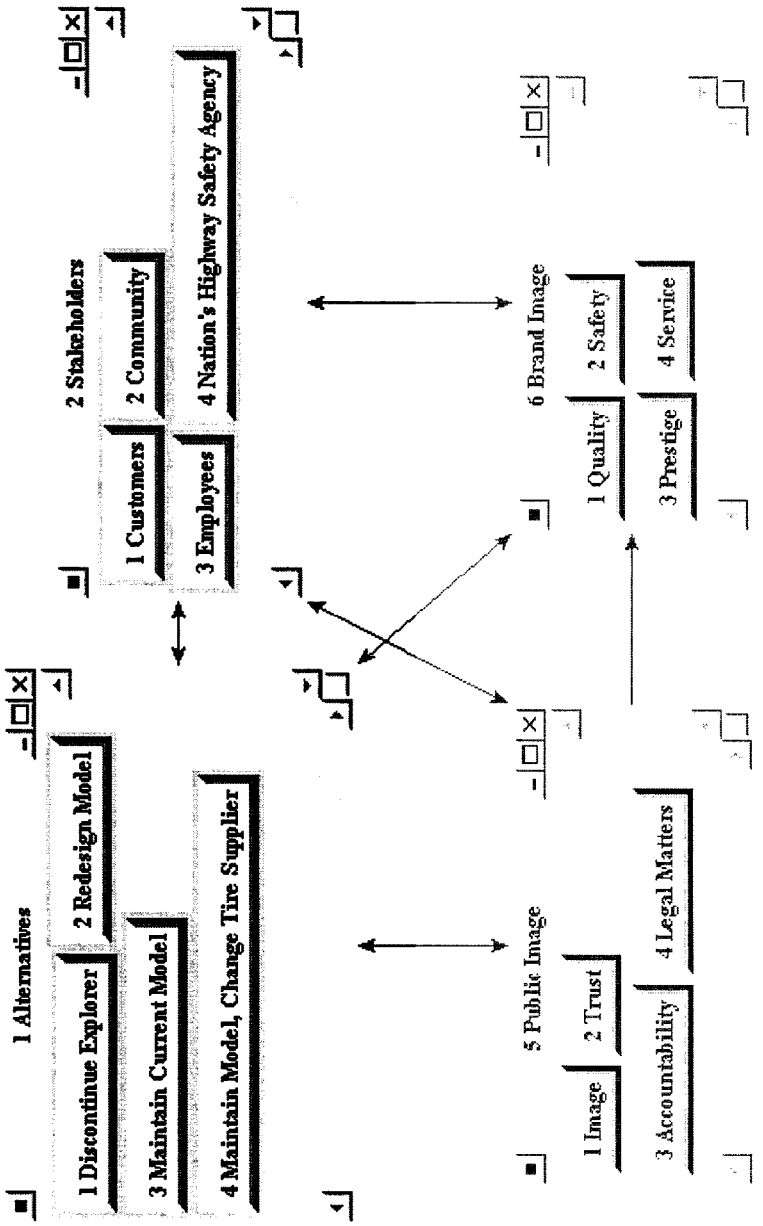


Figure 10. Micro View of Social Costs Network

5. RISKS MODEL

Unlike the Benefits and Costs models, the Risks model is slightly different. The Risks model contains indefinite interactions and results. In the case of Ford-Firestone risks are defined as the negative uncertainties in the decisions taken by Ford regarding the Ford Explorer/Firestone matters. We can classify risks into two categories, economic and social.

Economic risks refer to financial risks that may occur as a result of the decisions taken by Ford. For example, if the decision is to discontinue Explorer, there is a risk that Ford would jeopardize its relationship with Firestone which may impact its relationship with other Ford brands. Social risks describe other than financial risks that may occur as a result of the decision taken by Ford. For example, if the decision is to maintain the current Explorer model, there is a risk that the number of accidents to customers who drive this car would increase.

Economic Risks Clusters, Links and Judgments

Table 9 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters in the economic risks model are shown in Figures 11 and 12.

Table 9. Economic risks clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Tires Suppliers	Firestone, Goodyear, Michelin and Other tire suppliers.
Competition	▪ Ford's other SUV brands ▪ Ford affiliates' SUV brands ▪ Other companies' SUV brands
Public Image	Image, Trust, Accountability and Legal matters.
Cost of Resources	Lay off costs, Launching costs, Write off costs, and Production costs
Resources	Revenue, Production Capacity and Market Share.

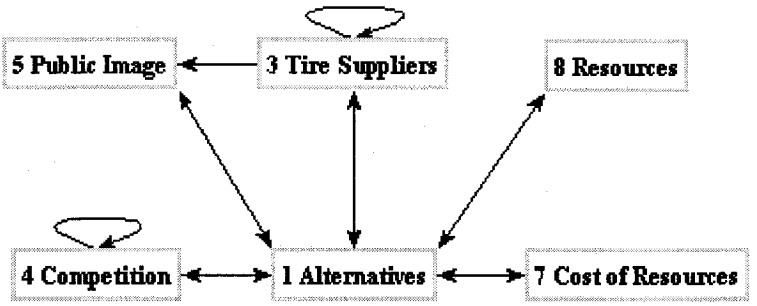


Figure 11. Macro View of Economic Risks Network

The 'tire suppliers' cluster refers to tire companies that may encounter economic risks based on the decision alternatives taken by Ford. This cluster would also affect the 'public image' cluster; more specifically, 'legal matters.' There is also an inter-dependence among the nodes in the 'tire suppliers' cluster. This is because what one tire supplier does may impact how the other tire suppliers react.

The 'competition' cluster has no link with any other clusters except the 'alternatives' cluster. It is clear that the decision taken by Ford regarding the Explorer would impact how the competition would behave. However, there is inter-dependence among the nodes in the 'competition' clusters. Similar to tire suppliers, what one competitor does may impact how the other competitors react.

The last two clusters that are impacted are the 'resources' and the 'cost of resources'. These two clusters refer to internal resources, both financial and non-financial resources. It is typical that the internal resources of a company would have economic risks due to a decision taken by the top management of the company. For example, there would be an economic risk for the revenue and lay off costs due to the decision taken.

Social Risks Clusters, Links and Judgments

Table 10 illustrates the clusters in this network and their respective elements. The inner and outer dependencies of clusters in the Social Benefits model are shown in Figures 13 and 14.

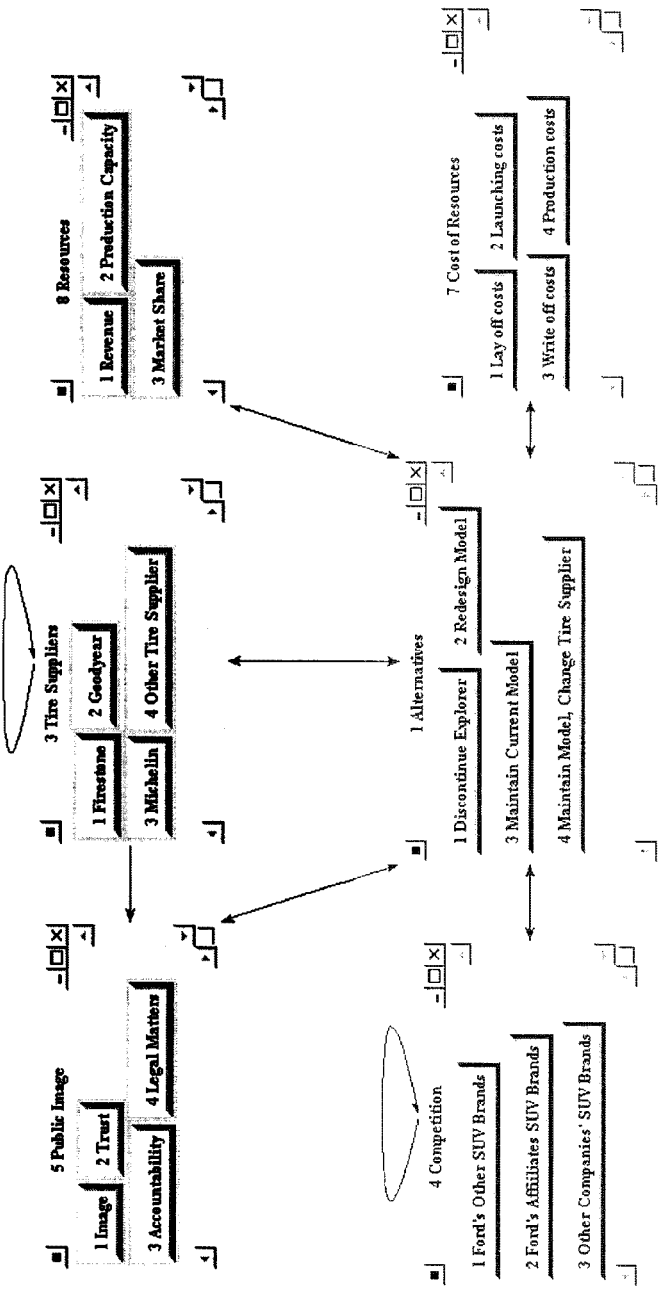


Figure 12. Micro View of Economic Risks Network

Table 10. Social risks clusters and elements

Clusters	Elements
Alternative Sites	▪ Discontinue Explorer production. ▪ Redesign the Explorer model. ▪ Maintain the production of Explorer Model. ▪ Maintain the production of Explorer Model, but change the tire supplier.
Stakeholders	Customers, Community, Employees and NHSA.
Public Image	Image, Trust, Accountability and Legal matters.
Brand Image	Quality, Safety, Prestige, and Service

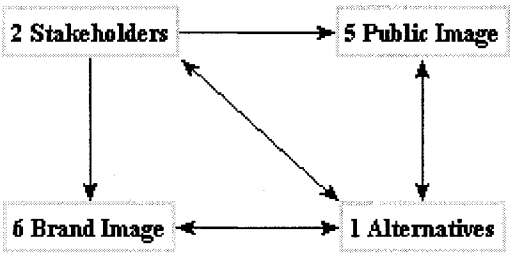


Figure 13. Macro View of Social Risks Network

The 'stakeholders' cluster refers to the people or group of people, who could have social risks, based on the different decision alternatives taken by Ford. This cluster practically affects all other clusters in this network, including the 'public image' and 'brand image' clusters. In this network, customers and community have higher impact on the network than the other two stakeholders.

The stakeholders can imply social risks to 'public image' cluster that would affect how they see the company's public image in terms of trust and image.

The stakeholders also affect the 'brand image' cluster along line similar to the 'public image' cluster. In this network, safety and prestige are considered to be more significant than the two types of image.

The 'stakeholders' cluster plays an important role in this network because it has the highest social risks related to the decisions taken by Ford.

Figure 14. Micro View of Social Risks Network

Synthesis of Judgments in the Risks Model

Both networks in the risks model have independent results that would then feed the higher-level network (the overall risks network). The combined results, from the Economic Risks and Social Risks networks, are shown in Table 11.

Table 11. Synthesized priorities in the Risks Model

	Risks		
	Economic	Social	
Alternatives	0.25	0.75	Synthesis
Discontinue Explorer	0.5591	0.1705	0.2676
Redesign Model	1.0000	1.0000	1.0000
Maintain Current Model	0.5613	0.0884	0.2066
Maintain Model, Change Tire Supplier	0.6982	0.4037	0.4773

The result in Table 11 indicates that from the risks point of view, the alternative decision of maintaining the current car model gives the highest risks, both from the economic and the social standpoints. The least risky alternative would be to redesign the model.

6. RATINGS AND SYNTHESIS

The final synthesized priorities of the alternatives for the benefits, costs and risks from tables 4, 8 and 11, respectively are given in Table 12.

Table 12. Synthesized Alternatives for B,C and R in Ideal Form

Values of Alternatives for B, C and R	Benefits (B)	Costs (C)	Risks (R)
Discontinue Explorer	1	0.2592	0.2676
Redesign Model	0.4145	0.7394	1
Maintain Current Model	0.1031	0.6081	0.2066
Maintain Model, Change Tire Supplier	0.5124	0.3443	0.4773

Strategic criteria are now used to rate the merits. Table 13 shows the priorities of the intensities in ideal form, that is, normalized by dividing each by the largest. These priorities were pairwise compared for preference and the same intensities derived by making pairwise comparisons (they are the same for all criteria).

Table 13. Intensity Values in Ideal Form for Rating B,C and R

Very High	High	Medium	Low	Very Low
1.000	0.578	0.235	0.118	0.063

Table 14 shows the strategic criteria and their subcriteria with their priorities obtained by using paired comparisons. The BCR merits are then rated, by first taking the ideal alternative for each merit, from Table 12, and then selecting the appropriate intensity, for that ideal alternative, from Table 13, for each strategic subcriterion. The overall weighted outcome unnormalized and normalized is shown on the left in Table 14.

Using these three normalized values for B, C, and R, the final ranking of the alternatives is shown in Table 15 computed with two different formulas: the multiplicative (ratio) and the additive (total). The total is what is of interest to us. In this case, the ratio outcome formula that is concerned with marginal returns, without considering the total resources needed to complete the projects, does not give the same ranking as the total outcome. Redesign is the best outcome, which is what Ford did anyway.[3] Both this analysis and Ford's decision where independently done at the same time in 2001.

Table 15. Final Ranking of Alternatives in Normalized Form

	Ratio (B/CR)	**Total (bB-cC-rR)**
Discontinue Explorer	1.69	0.017
Redesign Model	1.55	**0.074**
Maintain Current Model	0.239	-0.274
Maintain Model, Change Tire Supplier	**3.169**	0.006

[3] These results are supported by the decision taken by Ford to redesign the Explorer in March 2001.

Table 14. Rating of BCR with Respect to Strategic Subcriteria

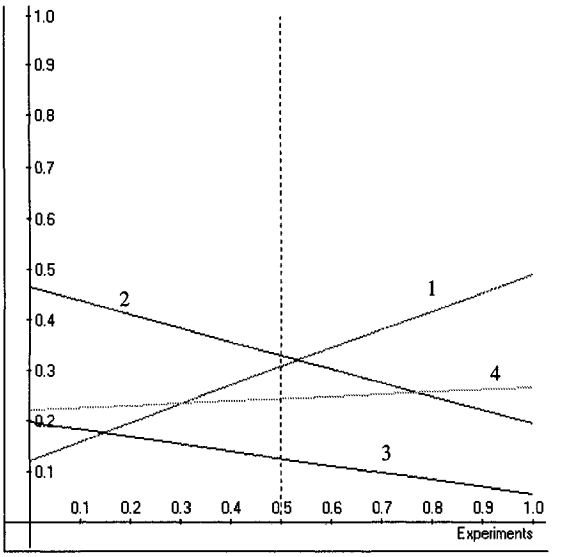
	Domestic Issue (.218)			International Relations (0.067)			Human Well Being (.714)				
Subcriteria	Ford Interests	Car Industry Interests	US Government Interests	Foreign Customers	Foreign Suppliers	Foreign Governments	Safety Factors	Confidence in Government	Confidence in Justice		
Weight	(0.731)	(0.081)	(0.188)	(0.637)	(0.105)	(0.258)	(0.731)	(0.188)	(0.881)		
Global Weight	0.160	0.018	0.041	0.043	0.007	0.017	0.522	0.135	0.058	Total	*Normalized*
Benefits	Very High (1.000)	High (0.578)	Medium (0.235)	Medium (0.235)	Low (0.118)	Medium (0.235)	Very High (1.000)	Very High (1.000)	High (0.578)	0.885	*b=0.485*
Costs	Very High (1.000)	Medium (0.235)	Low (0.118)	High (0.578)	Very Low (0.063)	Low (0.118)	Very High (1.000)	Very Low (0.063)	Very Low (0.063)	0.730	*c=0.400*
Risks	Medium (0.235)	Low (0.118)	Very Low (0.063)	Low (0.118)	Medium (0.235)	Low (0.118)	Medium (0.235)	Medium (0.235)	Very Low (0.063)	0.209	*r=0.115*

7. SENSITIVITY ANALYSIS

In order to determine when different alternatives become preferable, sensitivity analysis was performed by varying weights and ratings in the model. The analysis began by increasing (and decreasing) the weight of the Benefits (See Figure 15). Table 16 interprets the results of Figure 15.

Table 16. Ranking of alternatives as benefits increase/decrease

	Weight of Benefits				
Alternatives	< 0.147	[0.147,0.305)	[0.305,0.534)	[(0.534,0.765)	> 0.765
Discontinue Explorer	4	3	1	1	1
Redesign Model	1	1	2	2	3
Maintain Current Model	3	4	4	4	4
Maintain Model, Change Tire Supplier	2	2	3	3	2



1 – Discontinue Explorer
2 – Redesign Model
3 – Maintain Current Model
4 – Maintain Model, Change Tire Supplier

Figure 15. Sensitivity analysis of benefits

Next, sensitivity analysis was performed for the Costs variable. The results obtained by increasing the weight of the costs are as follows: redesign model, maintain current model, maintain model & change tire supplier, and discontinue the Explorer model production. This means that if the company perceives the costs as the most important criterion to make the decision, they would decide to redesign the model. From this result, one is led to conclude that this alternative seems to be the best choice from the costs standpoint. On the other hand, if the weight of the costs is decreased, the result would be to discontinue, redesign model, maintain model & change tire supplier, maintain current model, in that order. This means that the risks criterion appears to be more important than the benefits, which leads to the decision of discontinuing production of the Ford Explorer model.

The last criterion was the risks. When risks are increased the outcome was: redesign model, maintain model & change tire supplier, discontinue, maintain current model. The conclusion supports the initial thought that maintaining the current model (without changing the tire supplier) is the riskiest decision for the company to make. Finally, when the weight of the risks was decreased the results were: discontinue Explorer, redesign model, maintain model & change tire supplier, maintain current model.

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CHAPTER 7

PENNSYLVANIA HIGH-SPEED MAGLEV PROJECT

Philip Rackliffe and Paul Thompson
(Fall 2002)

1. INTRODUCTION

Transportation needs are steadily growing. The problem of how to meet these needs in the future is significant. High Speed Maglev may be the solution. It is designed to supplement, not replace existing transportation systems. The Federal Railroad Administration (FRA), of the U.S. Department of Transportation, is administering pre-construction engineering activities for a high-speed Maglev transportation system to commercialize this revenue ready technology for use in the United States. Pennsylvania has been selected as one of the two finalists in the U.S. to compete for this project and has provided the required state-funding match. As one of two remaining competitors in the United States for site selection and construction funding, we have a chance to bring this project to Pennsylvania. However, only one site will be chosen for the initial construction. Unified support is required throughout Pittsburgh and Pennsylvania.

The competing project sites will be evaluated against a set of criteria. These include adequate 'ridership', an acceptable corridor for installation, satisfaction of a real transportation need, national significance of the project, an in-place partnership, and the ability to demonstrate the technical capabilities of the technology.

The Pennsylvania High-Speed Maglev Project corridor would extend from the Pittsburgh International Airport to Greensburg, with intermediate stops in downtown Pittsburgh and Monroeville. This initial project would serve a population of approximately 2.4 million people in the Pittsburgh metropolitan area.

It is envisioned that this will be the first segment of a high-speed Maglev system that will cross Pennsylvania from Pittsburgh to Philadelphia with stops in Johnstown, Altoona, State College, Lewistown, Harrisburg, Lancaster, Paoli and eventually extend farther East to connect to the populous Northeast Corridor.

Future projects also envisioned include a Southern link to Wheeling, Morgantown, Clarksburg and Charleston, West Virginia and a Western link to Cleveland and Chicago. A Northern link would include Erie, Pennsylvania and Buffalo, New York.

The proposed route is illustrated in Figure 1. The Pennsylvania Project's route will connect the Pittsburgh International Airport to Downtown Pittsburgh, and the eastern suburbs of Monroeville and Greensburg. The route will cover 54 miles and will take less than 35 minutes including stops from start to end. Estimated trip times between MAGport™ Stations are as follows:

Airport (landside) to Airport (commuter)	1.5 min.
Airport (commuter) to Downtown	8.0 min.
Downtown to Monroeville	12.0 min.
Monroeville to Greensburg	9.0 min.

The Federal Railroad Administration's (FRA) Magnetic Levitation Transportation Technology Deployment Program (Maglev Deployment Program) was authorized by the Transportation Equity Act for the 21st. The FRA Maglev Deployment Program promotes the development and construction of an operating transportation system in the United States, employing magnetic levitation that is capable of safe use by the public at a speed in excess of 386 kilometers/hour (240 miles/hour).

The development of Maglev would provide an alternative transportation option to federal, state, and local transportation decision-makers that are seeking to alleviate congestion in airway and automotive corridors that result from increasing travel demand.

Maglev technology has the potential to maximize the utilization of an airport's capability as centers for intermodal transfer and travel by providing intermodal connections between airports and business districts. As such, Maglev systems could extend the usefulness of airport and highway infrastructure. Pennsylvania provides the ideal location to introduce this new technology. Its winding rivers, ridges, and topography provide a perfect place to install a proven technology as a show case for the region and proof of its applicability throughout the U.S.

Pittsburgh is an ideal location to begin this project. Both rivers and steep ridges uniquely challenge the Pittsburgh landscape. Primary automobile traffic access to Pittsburgh is limited in the east by the Squirrel Hill Tunnel, in the west by the Fort Pitt Tunnel and Fort Pitt Bridge and in the south by the Liberty Tunnels and Liberty Bridge. Pittsburgh International Airport is also ranked as the nation's first and the Worlds 3rd best airport. The installation of a Maglev system in the Pittsburgh area would extend the Pittsburgh airport into smaller towns making it more accessible and affordable for the average traveler.

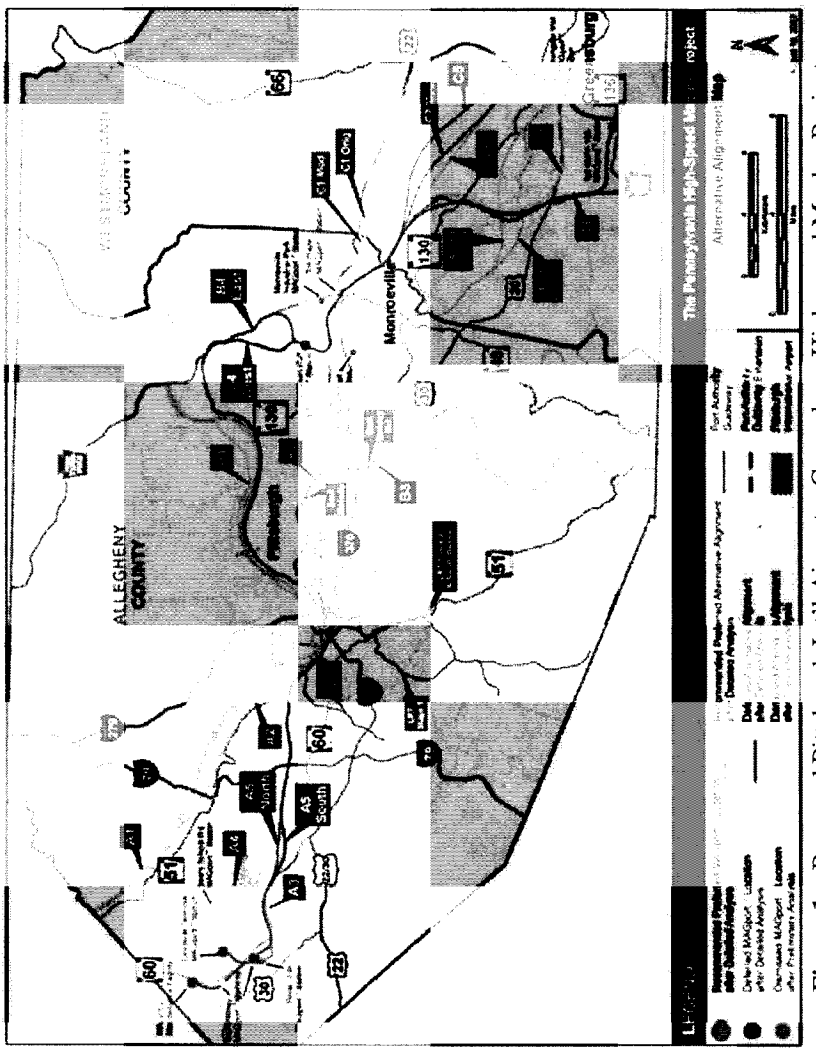

Figure 1. Proposed Pittsburgh Int'l Airport – Greensburg High-speed Maglev Project

Pittsburgh also has the necessary technical and manufacturing expertise to support the Maglev System for U.S. applications. The Transrapid elevated Maglev system with its dedicated right-of-way would be an ideal technology to help alleviate Pittsburgh's traffic problems. Using the ability to climb steep grades posed by Pittsburgh's hills while minimizing the disturbance to legacy structures and landmarks will also minimize the impacts associated with the installation of a Maglev system. The system would also create the start of an expanding regional system that will bring economic industry growth and jobs to the region while serving as the impetus for revitalization of the area.

2. ALTERNATIVES AND BOCR MODEL

The goal of the model was to determine which stance our regional governments, provided being granted federal funding for Maglev, should take. The options were:

- Accept the grant money and begin construction of Maglev
- Take a wait and see approach, based on results found in another city
- Reject the project entirely, foregoing at least in any foreseeable future, the adoption of the project.

The model was built using the BOCR (Benefits, Opportunities, Costs, and Risks) template.

Benefits

We classified benefits into two main subnets – *economic and social*. Economic held five clusters (Figure 2):

- Stakeholders (Community, Local Business, Business Travelers, and Local Government)
- Employment (New Jobs, Retain Jobs, and Project Specific Jobs)
- Business Development (Construction Industry, Existing Businesses, and Draw of Outside Companies)
- Time Element Positive (Commute Time and Worker Productivity).

Their interactions are given in Figure 2.

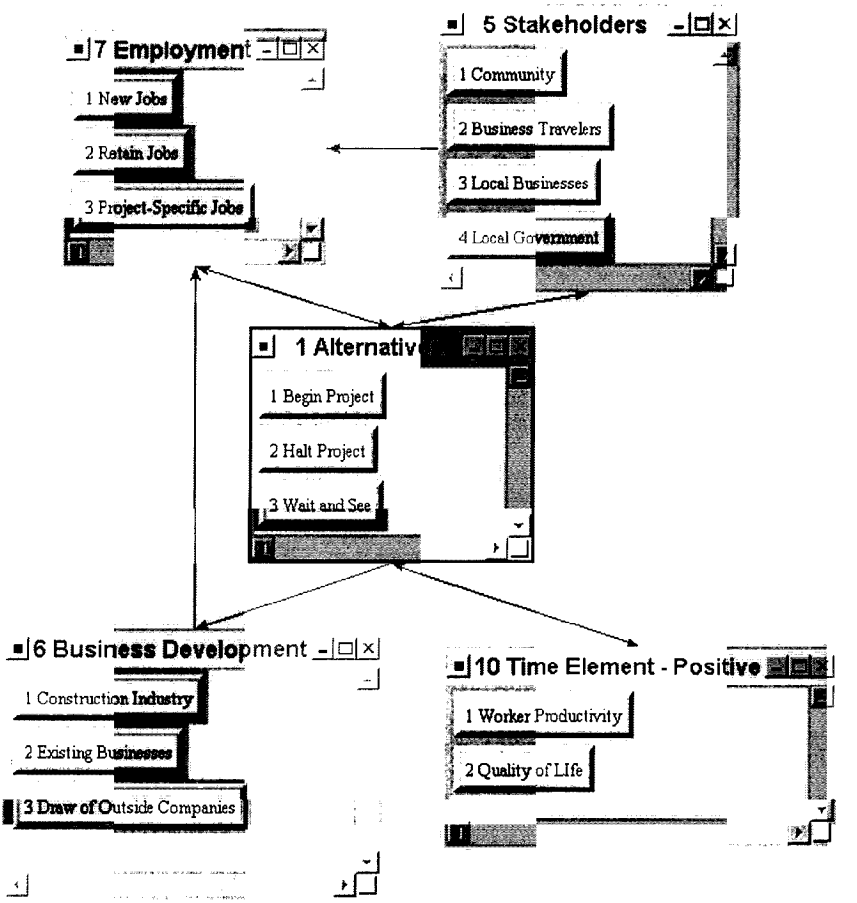

Figure 2. Economic Benefits Subnet

Of these clusters, some were more important than others:

	Stakeholders	Business Development	Employment	Time Element	Priorities
Stakeholders	1	1/2	1	3	0.2311
Business Development	2	1	2	5	0.4435
Employment	1	1/2	1	4	0.2499
Time Element	1/3	1/5	1/4	1	0.0755

Business Development and Employment are valued more than Stakeholders and Time Element in this case. Time Element might mean more under Social than Economic, since it factors in commute time. The Social Benefits clusters are shown in Figure 3.

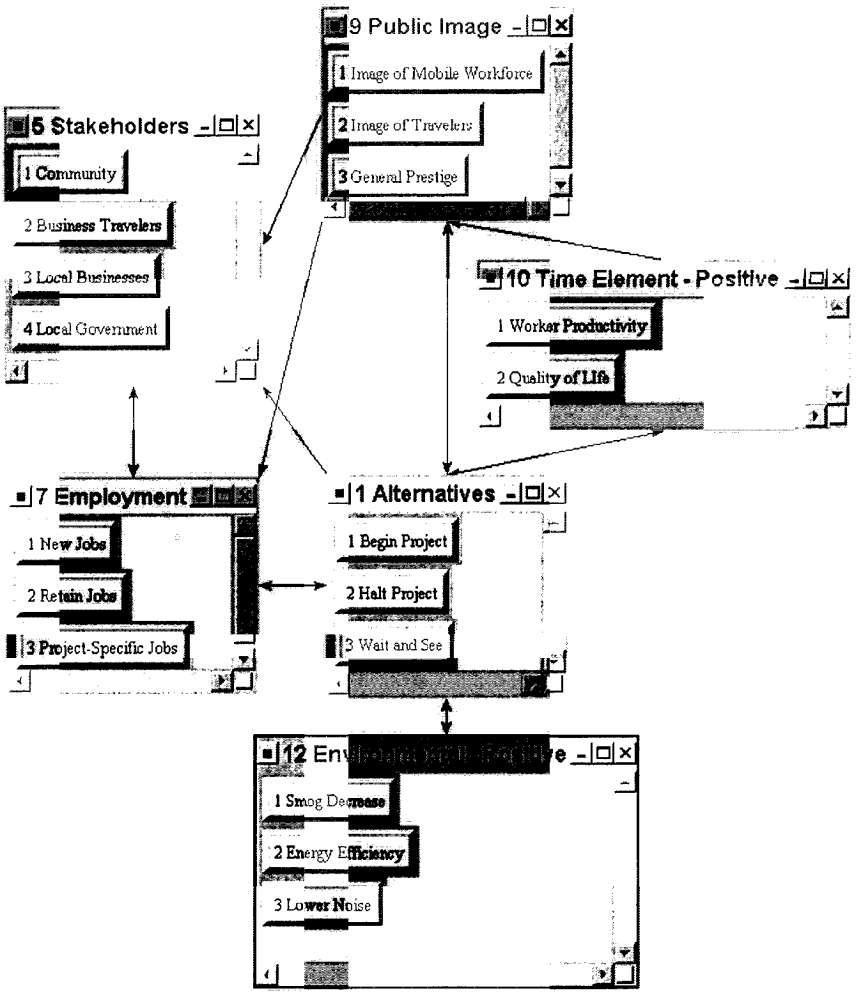

Figure 3. Social Benefits Subnet

Social benefits were quite different than economic benefits. This included Positive Environmental factors as well as Public Image.

Opportunities

Opportunities should be seen in a different light than benefits. From a high level we are looking at Political (Figure 4) and Social (Figure 5) opportunities versus Economic and Social Benefits. It seems that our politicians and local government especially have a chance to look very good if they can land Maglev.

We will see later that there is also a high risk factor. So that is weighed into our model as well.

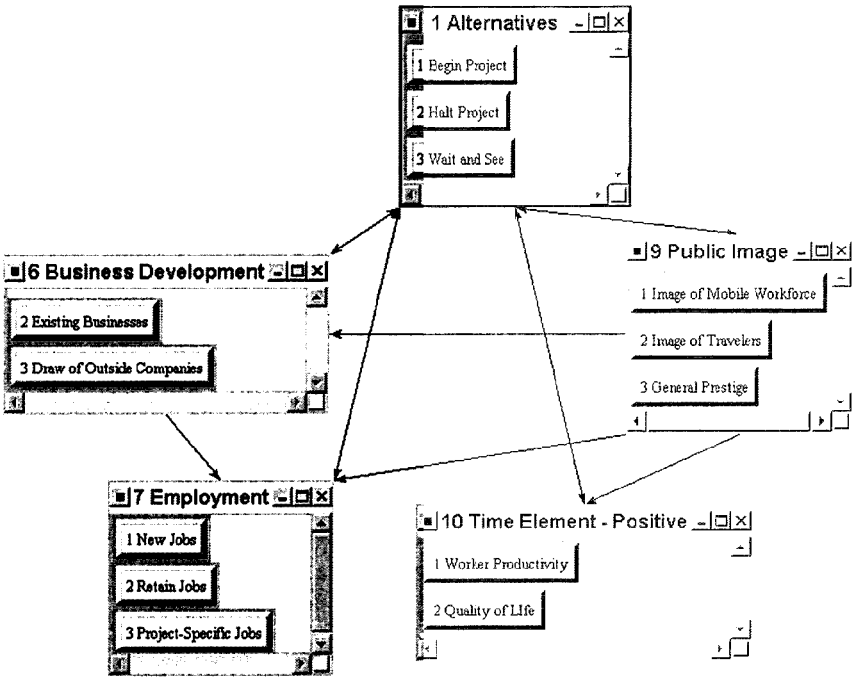

Figure 4. Political Opportunities Subnet

We find that Employment and Time Element-Positive were included in both. Employment is important socially as well as politically. Think of the politician trying to sway voters their way during times of high unemployment. As for Time Element-Positive, our local government (city and county both) would be seen in a positive light if its citizens enjoy shorter commute times and hence are more productive in terms of productivity. These are just two examples of how we decided what clusters to include in which subnets.

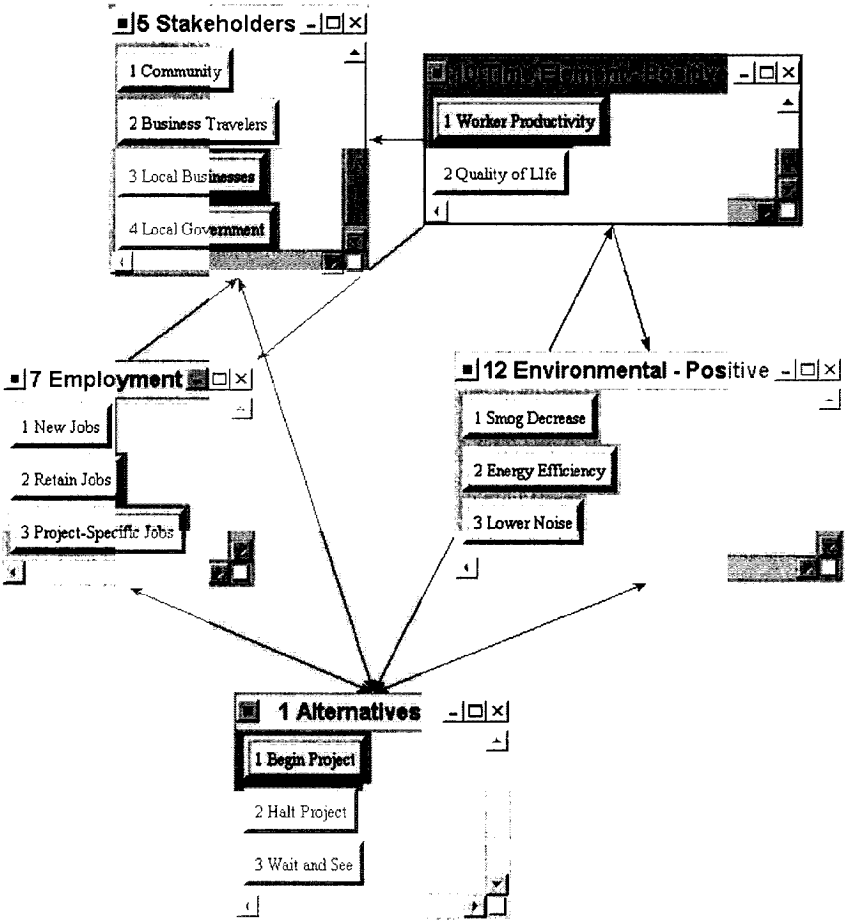

Figure 5. Social Opportunities Subnet

Costs

As the Benefits clusters present the positive side of moving forward with the Maglev project in Pittsburgh, the Cost clusters exhibit those factors that are detrimental to the Pro-Maglev argument. This is how the model balances out the pro and cons and ultimately yields a decision that incorporates all factors. For Costs, we had only Economic costs (Figure 6).

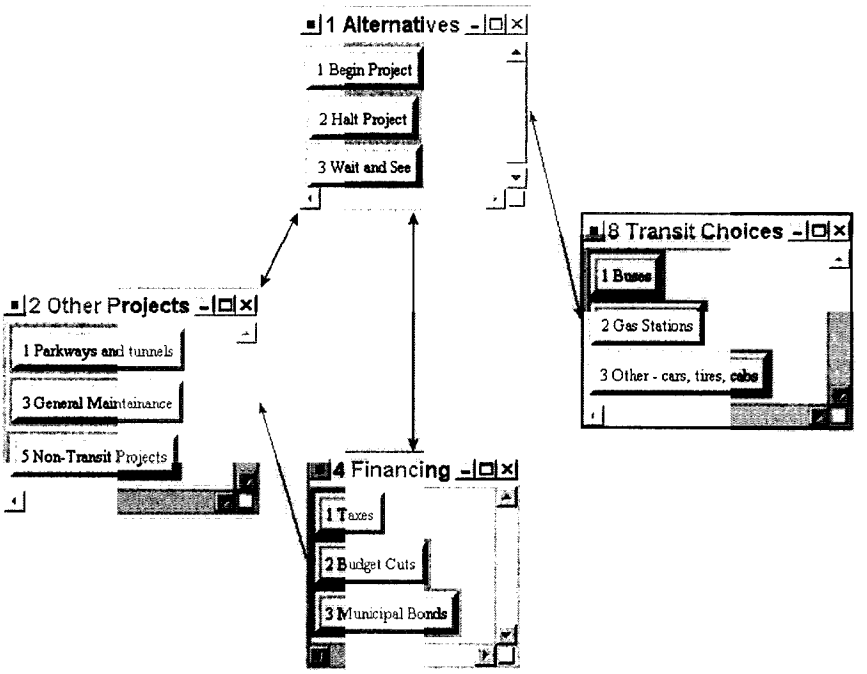

Figure 6. Economic Costs Subnet

Financing needs no explanation, for taxes, budget cuts, and municipal bonds cost people money. But to clarify Other Projects, we mean opportunity cost. If our region builds the Maglev system, what would we sacrifice? As for other means of transportation we mean those that would suffer should Maglev be given the go ahead. For instance, those that sell cars or tires would lose business.

Table 1 is a node comparison from Economic Costs.

Table 1. Comparisons and Priorities of "Other Projects" with respect to "Begin Project"

Other Projects	Parkway and Tunnels	General Maintenance	Non-transit Projects	Priorities
Parkway and Tunnels	1	1/2	4	0.3446
General Maintenance	2	1	4	0.5469
Non-transit Projects	1/4	1/4	1	0.1085

We assigned equal dominance of 'Parkways and Tunnels' and 'General Maintenance' over 'Non-transit Projects'. Although it is hard to decide which is more important than the other we said that Non-Transit projects were indeed NOT as important as either of the other two.

Risks

The Risks were broken down into two subnets – *Economic* (Figure 7) and *Political* (Figure 8). These risks would play a pivotal role in arriving at the final decision. Economic risks are huge, as the city of Pittsburgh may soon be responsible for a project that is worth several billion dollars. As are political risks so far as positive or negative news is reported, so will the reputation and 'coat-tail' hanging of the politicians.

The economic risks network is as follows:

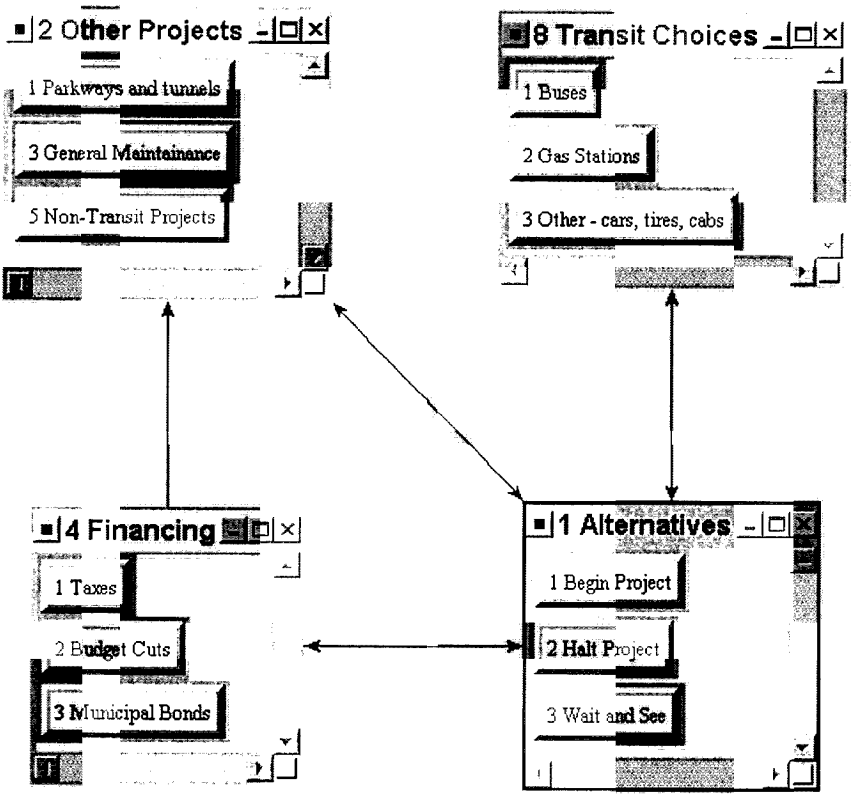

Figure 7. Economic Risks Subnet

The political risks were a little more complicated as more factors were imperative for the final decision (Figure 8).

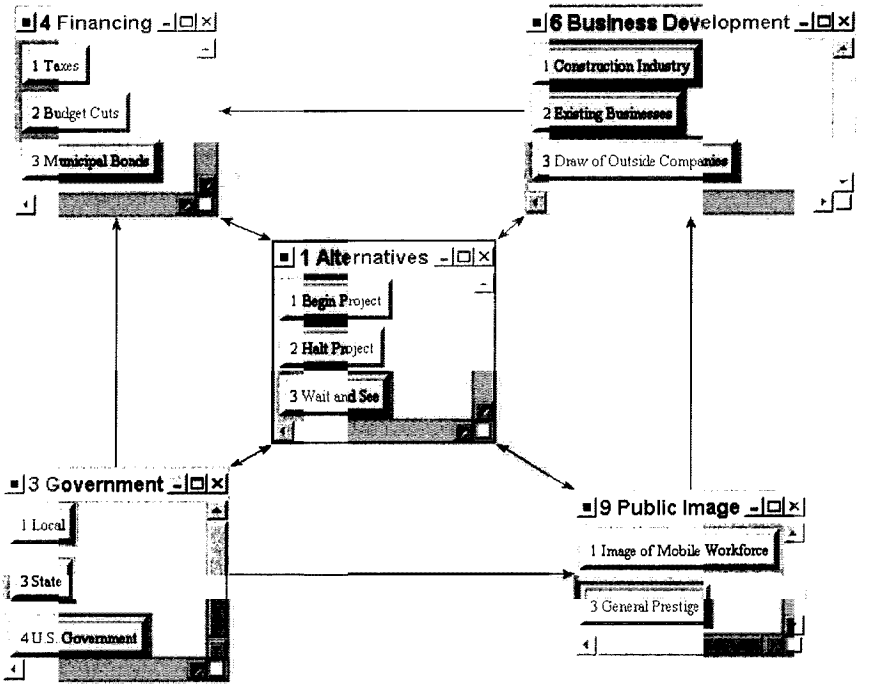

Figure 8. Political Risks Subnet

The priorities of the alternatives in ideal form obtained from the corresponding subnets are given in Table 2. Table 3 gives the synthesized priorities for the benefits, opportunities, costs and risks.

Table 2. Alternative Priorities under the Control Criteria

	Benefits		Opportunities		Costs	Risks	
	Economic	Social	Political	Social	Economic	Economic	Political
Alternatives	0.5	0.5	0.5	0.5	1	0.5	0.5
1 Begin Project	1	1	1	1	1	1	1
2 Halt Project	0.10919	0.143575	0.153293	0.125675	0.1958	0.123658	0.145029
3 Wait and See	0.288281	0.264983	0.289333	0.306567	0.350878	0.325767	0.310828

Table 3. BOCR Priorities

Alternatives	Benefits	Opportunities	Costs	Risks
1 Begin Project	1.0000	1.0000	1.0000	1.0000
2 Halt Project	0.1264	0.1395	0.1958	0.1343
3 Wait and See	0.2766	0.2979	0.3509	0.3183

Ratings

To determine the importance of benefits, opportunities, costs, and risks, they were rated with respect to the strategic criteria. The strategic criteria used were Business Development, Commuter Time, Political Motivation, and Public Attention. The scale design to rate the strategic criterion was: Very High, High, Medium, and Low. Comparisons were made for the rankings and the end result for the ratings as well as the resulting priorities for benefits, opportunities, costs and risks are shown in Table 4.

Table 4. BOCR Ratings

	Business Development	Commuter Time	Political Motivation	Public Attention	Normalized Priorities
	0.5516	0.2273	0.0769	0.1441	
Benefits	Very High	Very High	Medium	High	0.4495
Opportunities	High	Very High	Medium	High	0.2953
Costs	Low	Medium	Very High	Medium	0.1086
Risks	Low	Medium	High	Very High	0.1466
Intensities:	Very High 1.0000	High 0.4641	Medium 0.2080	Low 0.0978	

3. RESULTS

The final synthesized results from our model are shown in Table 5.

Table 5. Synthesized Priorities

Alternatives	BO/CR	bB+oO-cC-rR
1 Begin Project	1.0000	0.4897
2 Halt Project	0.6702	0.0571
3 Wait and See	0.7380	0.1276

Based on earlier assumptions, that there are three ways to approach the potential Maglev project, the local governments should accept the government funding and begin working on constructing the Maglev transportation system. The normalized result of .4897 for beginning the project is a great deal higher than both 'Wait and See' and 'Halt Project'. These results may have been somewhat different had others familiar with the situation taken on the same problem with the same decision making software. But we feel that others with our same knowledge of the subject would come to a similar finding.

4. SENSITIVITY ANALYSIS

Our model results could potentially change if our priority ratings are modified. Sensitivity analysis was completed to show the effects of these modifications.

Figures 9-12 examine the sensitivity analysis for the BOCR decision network.

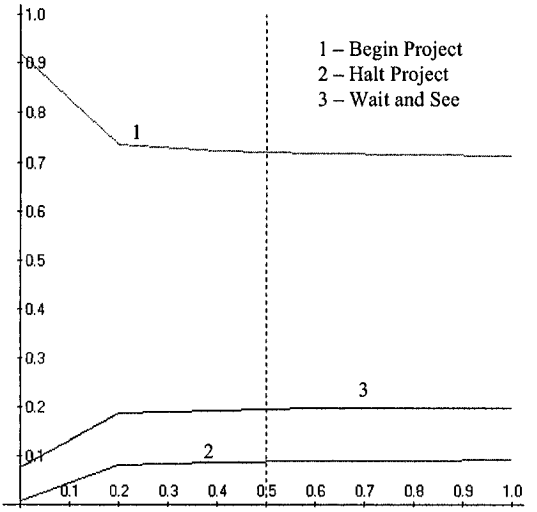

Figure 9. Sensitivity Analysis of Benefits

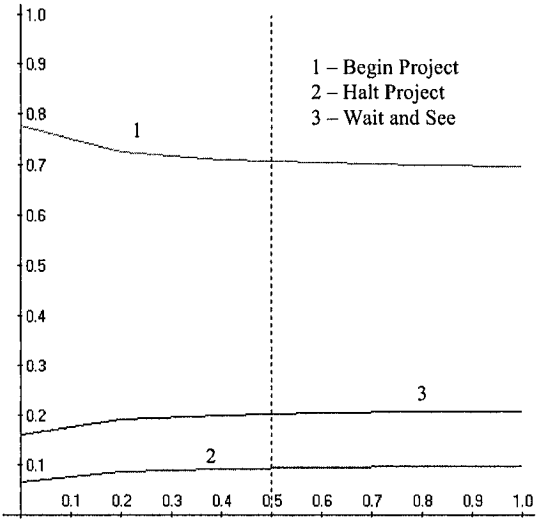

Figure 10. Sensitivity Analysis of Opportunities

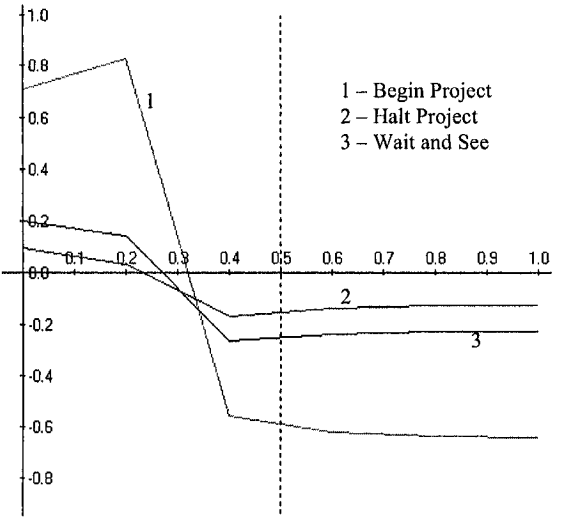

Figure 11. Sensitivity Analysis of Costs

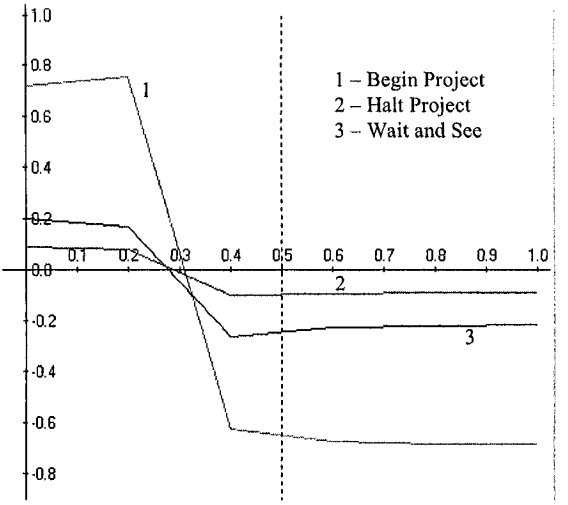

Figure 12. Sensitivity Analysis of Risks

The best choice under benefits and opportunities is always Begin Project. For costs and risks, once the emphasis on the criterion exceeds approximately 30 percent, Halt the Project becomes the dominant decision. Putting all the criteria together we see that overall Begin Project tends to dominate (Figure 13).

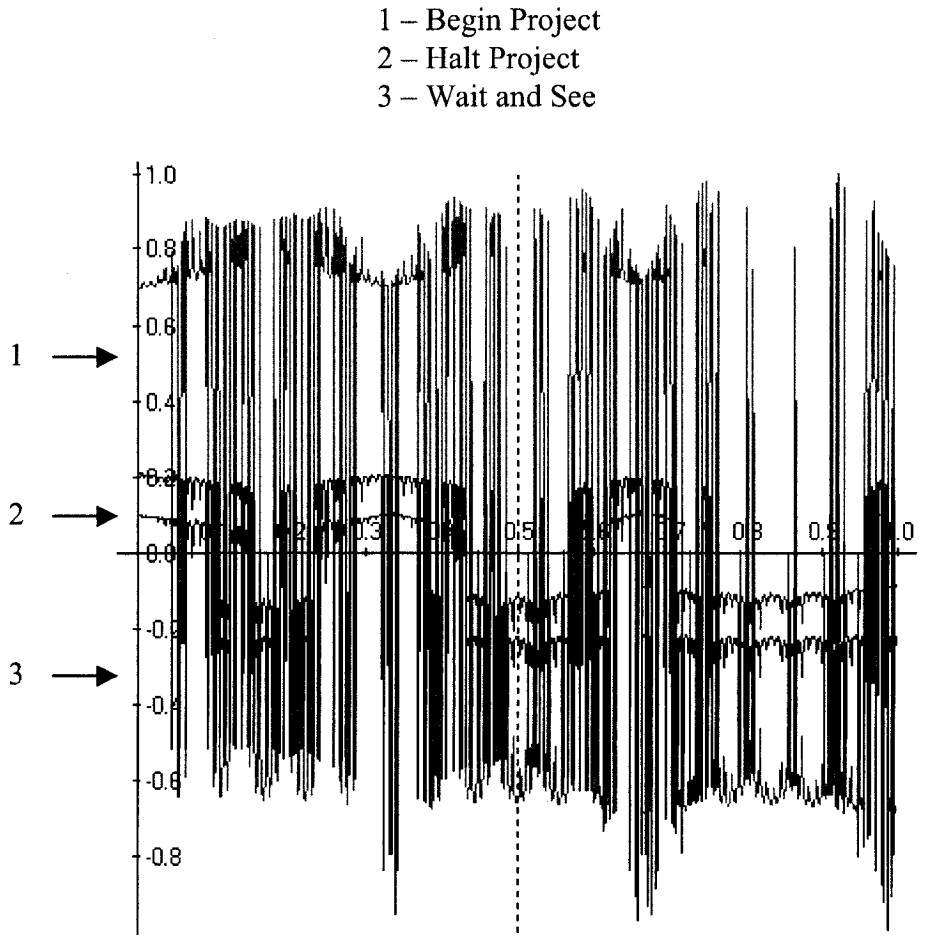

Figure 13. BOCR Sensitivity Analysis

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CHAPTER 8

U.S. ENERGY SECURITY

Jose D. Figueroa and Daryl R. Wood
(Winter 2004)

1. INTRODUCTION

There has been an ongoing debate in the United States ever since the Report of the National Energy Policy Development Group[1] was submitted for consideration by Vice President Dick Cheney to President George W. Bush on May 16, 2001. The statements and recommendations of the report have been so controversial since its public release that senate and house committee meetings have been held along with requests that the Vice President come before Congress to explain what was discussed behind closed doors.

Energy is a pivotal factor in society and will continue to be in the future so long as humanity is driven to develop technologies to meet its needs that are powered by energy. The U.S. faces a serious energy problem in the near future. How can the U.S. sustain its growth? What fuels will power its vehicles, heat its homes, and generate electricity that comes on with the flip of switch to turn the lights on?

An Analytic Network Process model, "Energy Security of the US", was developed to provide statistical support to intuition and judgment based on knowledge and expertise of the subject matter. The model takes into account all the significant factors and forces indicated by intuition to influence the direction of U.S. Energy Policy. This model was not designed to justify National Energy Policy advocated by Vice President Cheney, but to determine which of four alternatives provides the U.S. the best direction to secure its energy future. The alternatives are:

1. Status Quo
2. Energy Independence Emphasis
3. Complete Energy Independence
4. Comparative Advantage Approach

The ANP model has four feedback sub-networks of control criteria called benefits, opportunities, costs, and risks (BOCR). All four sub-networks have control criteria clusters that are specific to the BOCR that are used in this report.

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[1] National Energy Policy, May 16, 2001, "Report of the National Energy Policy Development Group, National Energy Policy", http://www.energy.gov/engine/doe/files/dynamic/1952003121758_national_energy_policy.pdf (16 May 2001).

Each control criterion cluster may have one or two level subcriteria clusters that are also specific to the parent node, cluster and sub-network. An alternatives sub-network is located at the top 70% priority nodes within each BOCR sub-network that is also specific to the issue being addressed at that point in the model. In addition, a strategic rating criteria model is developed to weight the BOCR in terms of Energy Security, International Competitiveness, and Environmental Quality.

There are many reports, papers, studies and presentations which say when, not if, the world and the US will be in an energy crisis. This statement in itself should be sufficient to keep one up at night thinking about what will "our way of life" be in ten or 20 years. The National Energy Policy report mentioned above provides a clear picture of what is happening and is forecasted for the U.S. (See Figure 1).

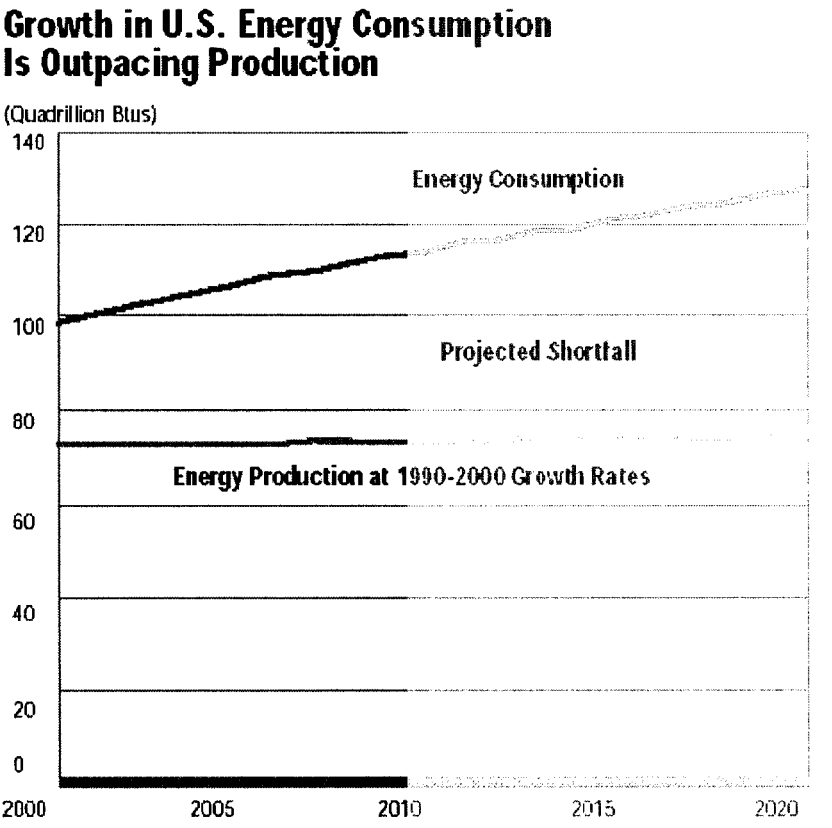

Figure 1. Growth in the U.S. Energy Consumption Is Outpacing Production

As forecasted for the next 20 years the energy consumption of the United States will outpace domestic energy production significantly. We have already felt this effect at the gasoline pump, home heating monthly winter bills, summer cooling electricity bills, the constant increase of everyday goods, and the jobs lost due to domestic companies outsourcing to foreign manufacturers in many cases due to the increase in domestic fuel costs.

Reports from Simmons & Company International indicates the following[2]:

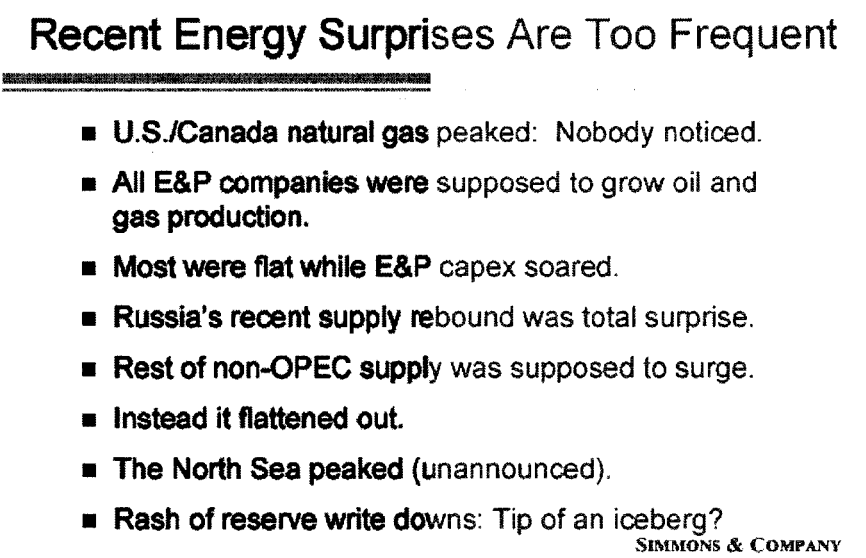

Figure 2. Simmons & Company International Presentation, February 24, 2004.

This one slide is supported by a consistent steady increase in natural gas prices from $2/MMBtu to more than $5/MMBTU for the month of March 2004 and gasoline prices averaging $1.70/gallon for regular grade for example. Some have stated that Liquefied Natural Gas (LNG) imports would provide the energy needed to meet U.S. demands with no cause for alarm since there have been over 33,000 tanker voyages with no major incident over the past 40 years. These statements now fall short since the January 2004 Algerian LNG complex accident that killed 27 people. There are other historical observations to make:

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[2] Mathew R. Simmons, February 24, 2004, "TheSaudi Arabian Oil Miracle", Presented at the Center for Strategic and International Studies, Washington, D.C.,.

1. Recent OPEC decision to reduce production in order to sustain the $38/barrel price of crude oil.
2. State aid[3] and bailouts of foreign companies that have injured U.S. power generation companies[4], such as the French Bailout of Alstom in September 2003.

Also with national security always on our minds due to the war on terrorism in Iraq, Afghanistan, Spain, and at home, Picture 3, there is an increasing need to determine what direction the United States should take with regard to its energy policy.

2. ANP MODEL DESCRIPTION

The Analytical Network Process model developed for this project has four feedback sub-networks of control criteria called benefits (Figure 3), opportunities (Figure 4), costs (Figure 5) and risks (Figure 6) (BOCR). Their sub-network control criteria, sub-criteria, nodes, and alternative sub-networks are identified in the next section.

BOCR Model

The BOCR model is a feedback sub-network that addresses the benefits, opportunities, costs, and risks associated to the energy security of the United States. Descriptions of each cluster and node with the clusters are indicated below. Nodes with an asterisk (*) have a subnetwork under them whose generic structure is given in Figure 7. This subnetwork may vary from node to node. For the sake of simplicity we will omit the minor differences.

An identification system is utilized throughout the model in order to maintain a hierarchal structure and order. For example, the first letter indicates whether it is a Benefit, Opportunities, Costs, or Risks cluster or node. The numbering system is self explanatory for a hierarchal structure.

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[3] According to the definition set out in Article 87(1) of the EC Treaty, State aid is incompatible with the common market if it is granted by a Member State or through State resources, if it distorts or threatens to distort competition by conferring an advantage on certain undertakings or the production of certain goods and if it is liable to affect trade between Member States. The form in which the aid is granted (interest rebates, tax reductions, loan guarantees, supply of goods or services on preferential terms or capital injections on terms not acceptable to a private investor) is irrelevant.

[4] Foster Wheeler is a power generation manufacturer and engineering company, which is expected to report a 50 percent decrease in its workforce in it 2003 annual report. Babcock and Wilcox is a U.S. boiler and power generation manufacturer which has filed for Chapter 11 protection several years ago.

B11 means B ➔ Benefits, 1 ➔ Political node, 2nd 1➔International node

(B) ***Benefits Cluster/Node Descriptions*** (Figure 3)

B1 Political Control Subcriteria
- **B11 International**
  - **B111 Bargaining Power.**
  - **B112 Energy Policy Leadership**
- **B12 Domestic Political Stability**

B2 Societal Control Subcriteria
- **B21 Technology Development**
- **B22 Sense of Well Being**
  - ***B221 Job Security**
  - **B222 National Pride**
  - **B223 Energy Assurance**
- ***B23 Controlling the Consumer Cost of Energy**

B3 Economic Control Subcriteria
- ***B31 Domestic Energy Cost Control**
- **B32 Domestic Economic Security**
  - ***B321 Domestic Employment Growth**
  - **B322 Domestic Manufacturing Growth**
- **B33 International Growth:** *The economic benefits associated with international import /export. Import in that the consumer has increased disposable income and export in that we have an abundant source of low cost of energy domestically increasing US exports and positively impacting the trade balance.*

B4 Technological Control Subcriteria
- **B41 Domestic Environmental Quality**
- **B42 Domestic Technology Superiority**
- **B43 International Trade:** *The benefit of exporting US technologies.*
- **B44 International Technology Leadership:** *The benefit of being the driving force related to energy policy and technologies.*

B5 National Security Control Subcriteria
- **B51 Military:** *Military benefits associated with energy security in the US. Should there be a conflict the military has abundant indigenous resources.*
- ***B52 Less Dependence on Foreign Influences**

B6 Environmental Control Subcriteria
- ***B61 Oil Peaking:** *The environmental benefits to oil peaking associated to the energy security of the US. i.e. Creates a driver for other fuel sources that are less harmful to the environment.*

(O) ***Opportunities Cluster/Node Descriptions*** *(Figure 4)*

O1 Political Control Subcriteria
- **O11 International**
  - **O111 Bargaining Power**

O112 Energy Policy Leadership
***O12 Domestic Political Stability.**
O2 Economic Control Subcriteria
O21 Domestic Energy Cost Control
O22 Domestic Economic Security
O221 Domestic Employment Growth
***O222 Domestic Manufacturing Growth**
***O23 International Growth.**
***O24 Oil Peaking**
O3 Technological Control Subcriteria
O31 Domestic Environmental Quality
O32 Domestic Technology Superiority
O33 International Trade
O34 International Technology Leadership

(C) *Costs Cluster/Node Descriptions (Figure 5)*

C1 Political Control Subcriteria
C11 International
C111 Bargaining Power: *The loss of international political bargaining power.*
C112 Foreign Political Backlash
C12 Domestic - Special Interest Groups: *Domestic political costs from special interests groups.*
C121 Environmental: *Political costs by environmental special interest groups.*
C122 Business: *Political costs by business related special interest groups.*
C2 Societal Control Subcriteria
C21 Sense of Well Being
C211 Petroleum products: *Society's sense of well being related to the amount of petroleum included in the energy mix.*
C212 Coal: *Society's well being associated to the percentage of coal utilized in the energy mix.*
C213 LNG: *Society's sense of well being associated with LNG as part of the energy mix.*
C214 Natural Gas: *The cost associated to society's sense of well being related to natural gas.*
C215 Hydrogen Economy: *The cost associated to society's sense of well being related to hydrogen.*
C216 Nuclear: *The cost associated to society's sense of well being related to nuclear.*
C217 Renewable: *The cost associated to society's sense of well being related to renewables.*
C22 Short-term consumer cost increase: *The short term energy cost increase associated with the energy security of the US.*

C3 Economic Control Subcriteria

C31 Domestic

***C311 Domestic Employment Loss:** *The domestic economic costs due to employment loss associated to the energy security of the US.*

***C312 Domestic Grid Instability:** *The economic costs associated with grid instability based on the energy mix.*

C32 International

C321 International Exports: *The costs associated with international exports. Exports may become more expensive since US investments and FDI are greater domestically than previously.*

C322 International Trade/Tariffs/Sanctions

C4 Technological Control Subcriteria

C41 Domestic R&D Costs

C42 Domestic Deployment Costs

C43 Domestic Transition Costs: *The costs associated to transitioning from our current energy mix to a moderately to significant energy mix.*

C44 International Trade Costs: *The costs associated by foreign concerns to our energy security policy, especially when it may affect their trade balance with the US.*

C5 National Security Control Subcriteria

C51 Increased Terrorism: *Costs due to terrorism. Since US is no longer as dependent on foreign sources of fuel, then a cascade effect in all sectors of the economy are expected. Outsourcing may not be required.*

***C52 Oil Peaking**

(R) ***Risks Cluster/Node Descriptions*** *(Figure 6)*

R1 Energy Policy Failure Control Subcriteria

R11 International Backlash: *The political risks from an International backlash.*

R12 Domestic Instability: *The political instability that will be created due to opposing sides of the energy policy issue. Should it not work, the two political parties would blame the other leading to little or no compromising on any political issue.*

***R13 Economic Calamity:** *The political risks associated due to an economic calamity because the correct energy security policy was not implemented.*

R14 Society: *The political risks associated to the unrest and discontent with the political leaders, i.e. civil unrest.*

R15 National Security Compromised: *description*

R2 Technological Control Subcriteria.

R21 Fuel Choice: *The technological risks associated with the fuel mix selected to ensure the energy security of the US.*

R121 Environmental: *Political costs by environmental special interest groups.*

C122 Business: *Political costs by business related special interest groups associated with the energy security of the US.*

R22 Research and Development: *The technological risks associated with R&D to support the energy security policy of the US.*

R23 Infrastructure: *The technological risks associated to infrastructure impacts that would support the energy security policy of the US.*

R3 Environmental Control Subcriteria

R31 Increased Emissions

***R32 Political**

R33 Health: *The health risks due to environmental emissions associated with the energy security policy of the US.*

R34 Fuel Choice: *The environmental risks associated with the fuel mix selected for the energy security of the US.*

***R341 Petroleum Products.**

R342 Coal

R343 LNG

R344 Natural Gas

R345 Hydrogen Economy

***R346 Nuclear**

R347 Renewables

R4 Economic Control Subcriteria

***R41 Oil Peaking**

Strategic Rating Model

The strategic rating model was developed separately to obtain the weighting values of the BOCR against three fundamental criteria associated with the energy security of the United States. Those criteria are Energy Security, International Competitiveness, and Environmental Quality[5]. A High, Moderate, and Low category scale was used to rate the criteria against the BOCR specific to the highest alternative from the BOCR model. In the case of Benefits and Opportunities it was the Energy Independence Emphasis, and for Costs and Risks it was the Comparative Advantage Approach.

i. Criteria Description

The three criteria used to answer the strategic rating model goal, "What direction should the United States energy policy provide?" are energy security, international competitiveness, and environmental quality.

[5] US Department of Energy, February 2004,"Hydrogen Posture Plan – An Integrated Research, Development, and Demonstration Plan".

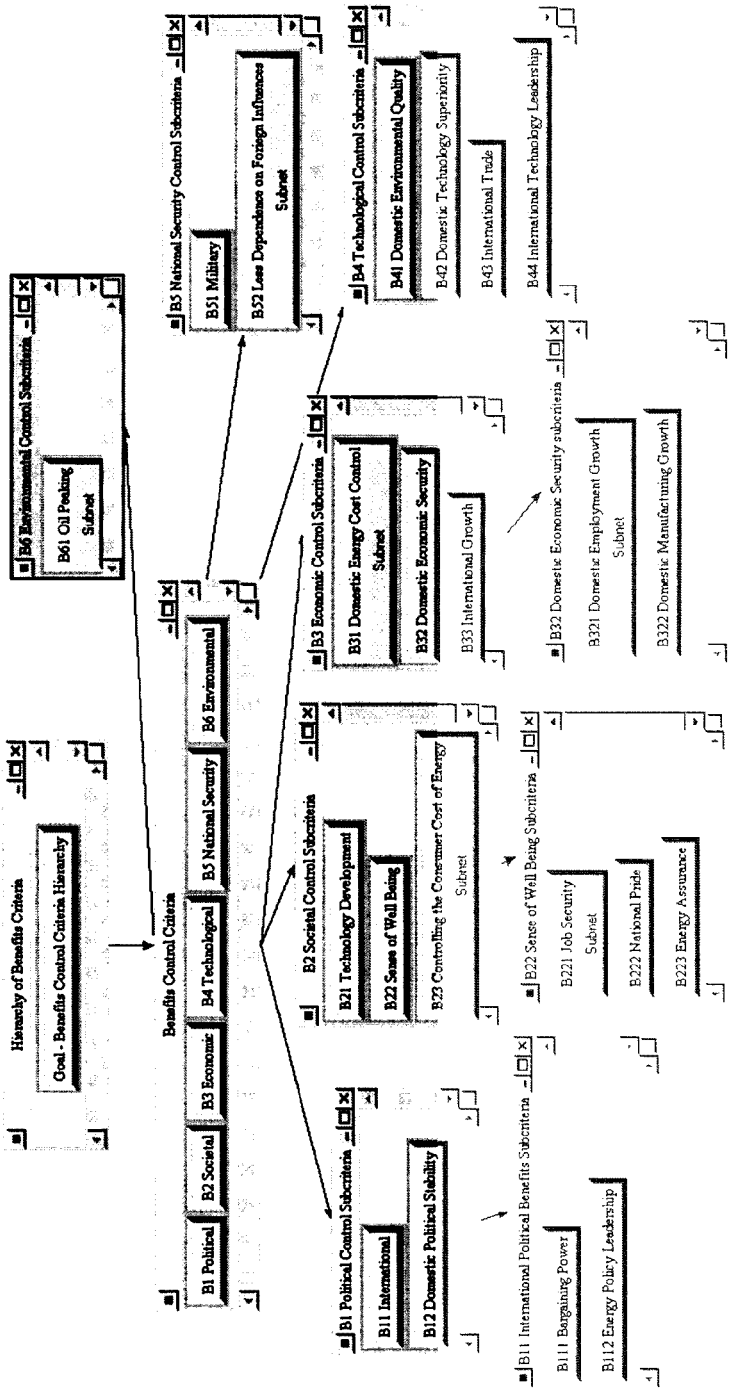

Figure 3. Benefits subnet

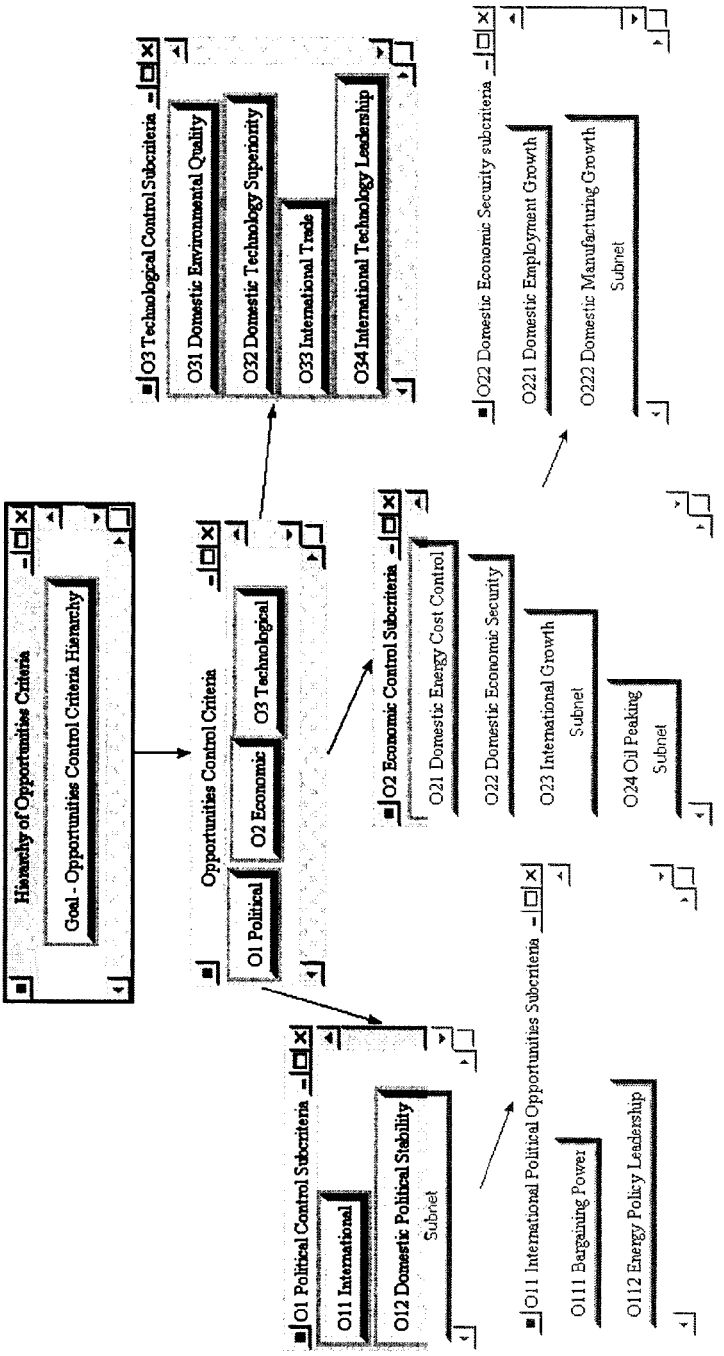

Figure 4. Opportunities subnet

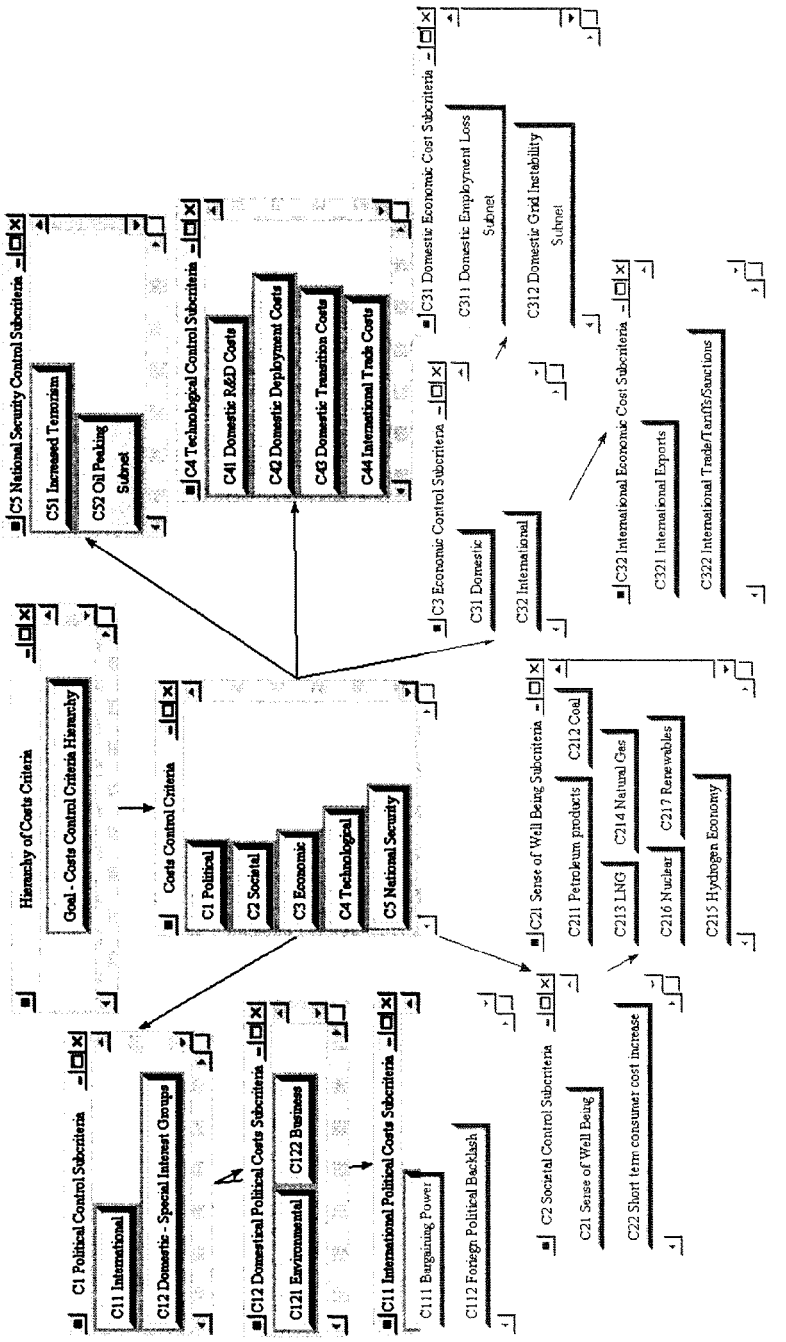

Figure 5. Costs subnet

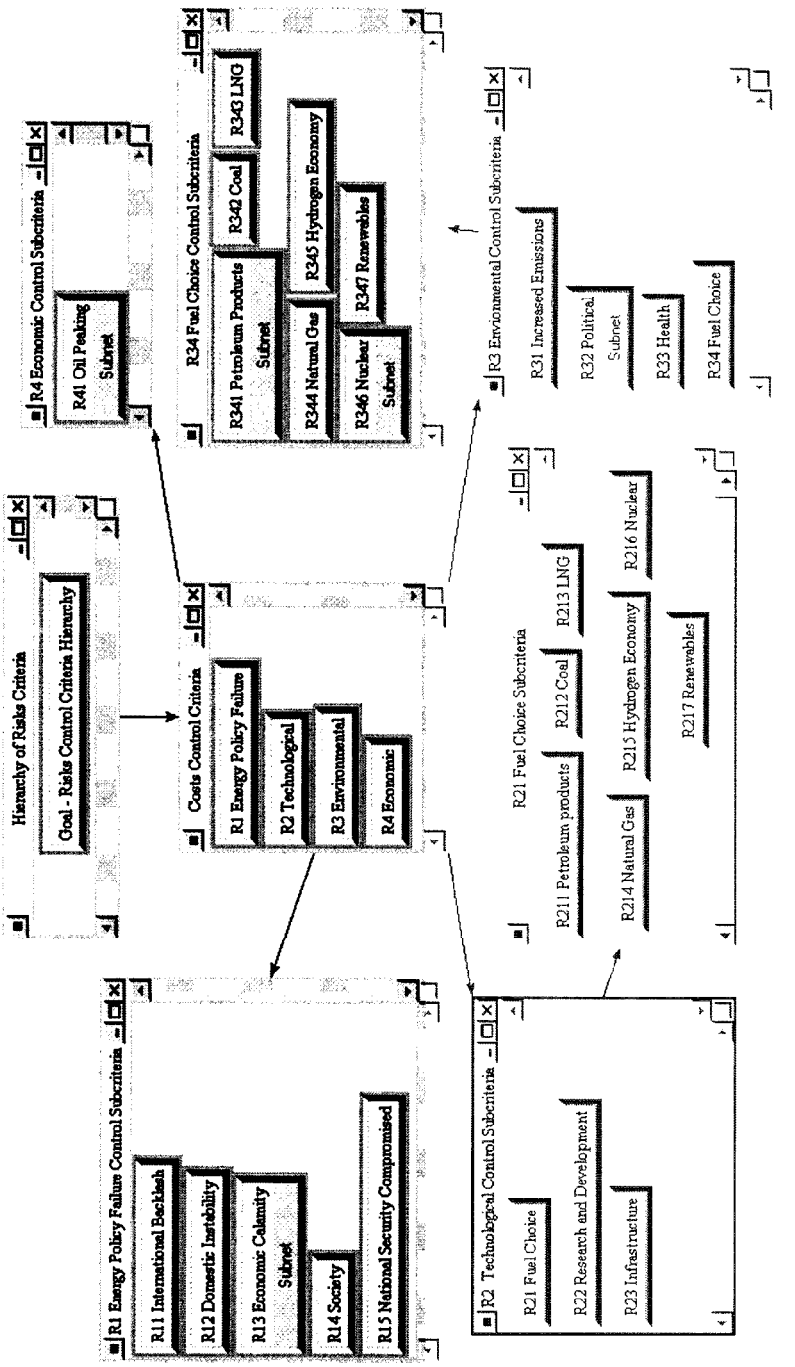

Figure 6. Risks subnet

ii. Alternatives Description

The role of alternatives for the strategic rating model is played by the benefits, opportunities, costs, and risks.

1. **Benefits**
   The alternative considered for Benefits against the three criteria indicated was energy independence emphasis. The rating chosen for the three criteria was high for energy security, high for international competitiveness and low for environmental quality. A low was chosen for environmental quality for two reasons. They were that sufficient environmental technologies existed to maintain a satisfactory level of environmental quality in the US from US produced emissions and that depending on the fuels being used from a particular point source the environmental quality might be better or worse dependent on the regulations at the time.

2. **Opportunities**
   The alternative considered for Opportunities against the three criteria was energy independence emphasis. The rating chosen for the three criteria was high for energy security, high for international competitiveness and moderate for environmental quality. A moderate factor was chosen for environmental quality because it was believed that advancements in technology to mitigate emissions from point or distributive sources would be developed. These developments in turn could create economic opportunities domestically and internationally through imports. The technology leadership that the US would have would not only reduce US produced emissions but those generated by foreign countries that pollute the US due to global effects.

3. **Costs**
   The alternative considered for Costs against the three criteria was comparative advantage approach. The rating chosen for the three criteria was moderate for energy security, moderate for international competitiveness and low for environmental quality. A moderate factor was chosen for energy security and international competitiveness because many of the technologies needed to generate efficient power cycles have been developed or at applied research stages of development. True that there may be breakthroughs in science that could alter the power generation cycle but that option was not considered in this analysis. In addition, a comparative approach as an energy policy would provide costs associated to the market forces and international influences associated with the energy production countries. One example is OPEC's decision to decrease production levels in order to maintain high prices. The control that OPEC has and other fuel producing nations which reside in

chaotic regions of the world only increases the costs to the US as it relates to politics, economy, society, international competitiveness, and national security.

4. **Risks**

The alternative considered for Risks against the three criteria was comparative advantage approach. The rating chosen for the three criteria was high for energy security, moderate for international competitiveness and low for environmental quality. A high was chosen for energy security because foreign influences would determine the availability of the fuel that drives our economy that in turn determines or standard of living and the potential of the nation. Moderate for International competitiveness for the same reasons as energy security but offset slightly by the fact hat the Unites States produces/invents products that cannot be initially obtained anywhere else in the world. A low rank for environmental quality because the US would most likely become more dependent on natural gas or LNG which is significantly environmentally friendly compared to coal or nuclear (Environmental equipment required for coal and nuclear to match less equipment required natural gas systems).

Alternatives Model

The alternatives model is shown in Figure 7. It is a template that was used to indicate all of the influences as they relate to the alternatives and each other. It is a very complex sub-network that was modified according to the high priority node within each BOCR sub-network. Specific information is provided herein to demonstrate that the template was useful in minimizing the model development time. In some cases other clusters and nodes were added because they were relevant to the point in the model being considered. Descriptions of the nodes were not included because they were considered self-explanatory.

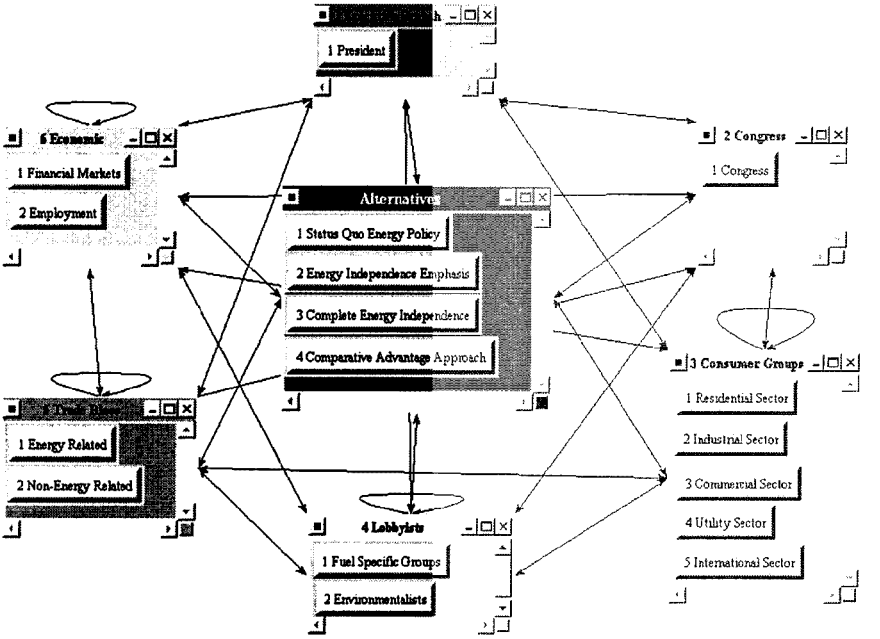

Figure 7. Alternatives Subnet Model Template

The four alternatives considered for this model were selected because it provided a range of options that went from a comparative advantage approach to complete energy independence. They ranged from globalization to isolationism, respectively.

Status Quo Approach

The status quo approach represents current approaches to the energy security of the United States. This takes into consideration that US fossil fuel imports have reached an all time high of 60% to a domestic fuel source of 40%. The actual breakdown is not considered at this level instead an indication of the 60/40 split between imports and domestic fuel sources was the point under consideration.

Energy Independence Emphasis

The energy independence emphasis is the direct reciprocal of the status quo approach that is to have a 40/60 split between imports and domestic fuel sources respectively. This approach would provide energy security with creating a sentiment that the US was moving toward isolationism.

Complete Energy Independence

The complete energy independence approach relates to 100% dependence on domestic resources. This was considered as one extreme that would lead to isolationism in the world fuel market and potentially a risky and costly proposition with little benefits and opportunities.

Comparative Advantage Approach

The comparative advantage approach took the direct opposite approach to complete energy independence. It considered a market driven US energy policy. This approach would only use domestic sources of fossil fuels if it were economical. There are obvious risks and costs associated with this approach but also considered it from a free markets perspective and a potential desire of the US population or political forces to be driven by a particular fuel which the US has limited reserves.

3. BENEFITS, OPPORTUNITIES, COSTS AND RISKS MODEL

The BOCR model illustrated in Figure 8 is the top most part of the model that has its own sub-networks specific to the benefit, opportunities, costs or risks associated to the energy security of the U.S. No two sub-networks are alike.

This section will elaborate on the different aspects of the model and its results. While the editorial comments may be short it is only because the figures state the results or what is being shown the best. Where further discussion it is given if warranted.

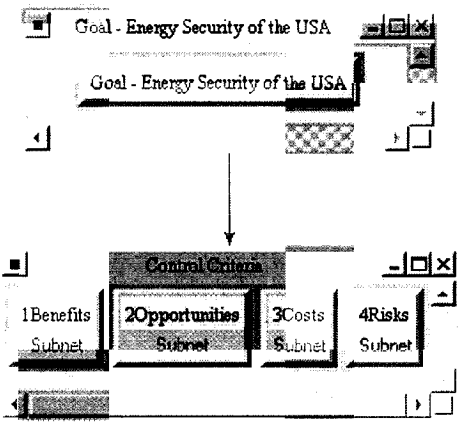

Figure 8. BOCR Model

Benefits Model

The Benefits sub-network illustrated in Figure 2 begins to show the complexity of the model. In this sub-network there are six alternative sub-networks corresponding to the nodes B221, B23, B31, B321, B52 and B61. The matrix illustrated in Table 1 shows the cluster pairwise comparison values for the benefits control criteria. Table 2 gives the synthesized priorities of all the benefits criteria.

Table 1. Pairwise comparisons and priorities of benefits control criteria

	Political	Societal	Economic	Technological	National	Environmental	Priorities
Political	1	1/5	1/6	1/3	1/7	1/3	0.0520
Societal	5	1	1/2	3	1	1	0.2977
Economic	6	2	1	3	4	2	0.2588
Technological	3	1/3	1/3	1	1/3	1/4	0.0739
National	7	1	1/4	3	1	1/2	0.0689
Environmental	3	1	1/2	4	2	1	0.2487

Table 2. Benefits priorities

Goal - Benefits Control Criteria Hierarchy	Normalized By Cluster		Limiting Priorities
B1 Political	0.0520		0.0227
B11 International	0.2500		0.0057
B111 Bargaining Power		0.8572	0.0049
B112 Energy Policy Leadership		0.1428	0.0008
B12 Domestic Political Stability	0.7500		0.0170
B2 Societal	0.2977		0.1301
B21 Technology Development	0.1005		0.0131
B22 Sense of Well Being	0.4664		0.0607
B221 Job Security		0.6483	**0.0393**
B222 National Pride		0.1220	0.0074
B223 Energy Assurance		0.2297	0.0139
B23 Controlling the Consumer Cost of Energy	0.4331		**0.0563**
B3 Economic	0.2588		0.1131
B31 Domestic Energy Cost Control	0.3325		**0.0376**
B32 Domestic Economic Security	0.5278		0.0597
B321 Domestic Employment Growth		0.6667	**0.0398**
B322 Domestic Manufacturing Growth		0.3333	0.0199
B33 International Growth	0.1397		0.0158
B4 Technological	0.0739		0.0323
B41 Domestic Environmental Quality	0.3042		0.0098
B42 Domestic Technology Superiority	0.1205		0.0039
B43 International Trade	0.4643		0.0150
B44 International Technology Leadership	0.1110		0.0036
B5 National Security	0.0689		0.0301
B51 Military	0.2500		0.0075
B52 Less Dependence on Foriegn Influences	0.7500		**0.0226**
B6 Environmental	0.2487		0.1087
B61 Oil Peaking		1.0000	**0.1087**

Opportunities Model

The Opportunities sub-network illustrated in Figure 3 shows that there are

differences in the BOCR sub-networks due to the question that is being addressed. In this sub-network there are four alternative sub-networks corresponding to the nodes O12, O222, O23 and O24.

The matrix illustrated in Table 3 shows the cluster pairwise comparison values for the opportunities control criteria. Table 4 shows the synthesized priorities of the opportunities criteria.

Table 3. Pairwise comparisons and priorities of opportunities control criteria

	Political	Economic	Technological	Priorities
Political	1	1/3	4	0.2628
Economic	3	1	7	0.6586
Technological	4	1/7	1	0.0786

Table 4. Opportunities Priorities

Goal - Opportunities Control Criteria Hierarchy	Normalized By Cluster	Limiting Priorities
O1 Political	0.2628	0.1154
O11 International	0.1667	0.0192
O111 Bargaining Power	0.7500	0.0144
O112 Energy Policy Leadership	0.2500	0.0048
O12 Domestic Political Stability	0.8333	0.0962
O2 Economic	0.6586	0.2893
O21 Domestic Energy Cost Control	0.0877	0.0254
O22 Domestic Economic Security	0.3533	0.1022
O221 Domestic Employment Growth	0.3333	0.0341
O222 Domestic Manufacturing Growth	0.6667	0.0681
O23 International Growth	0.1305	0.0378
O24 Oil Peaking	0.4285	0.1240
O3 Technological	0.0786	0.0345
O31 Domestic Environmental Quality	0.1702	0.0059
O32 Domestic Technology Superiority	0.2904	0.0100
O33 International Trade	0.4215	0.0146
O34 International Technology Leadership	0.1180	0.0041

Costs Model

The costs sub-network illustrated in Figure 4 shows the differences compared to the benefits and opportunities sub-networks. Cluster C5 National Security is new and introduces the costs associated to Increased Terrorism and Oil Peaking. In this sub-network there are only three alternative sub-networks (C311, C312 and C52) because of their impact on costs. What is interesting is that the numerous other nodes are not even close to being significant but do play a role in elevating the Alternative sub-network nodes.

The matrix illustrated in Table 5 shows the cluster pairwise comparison values for the costs control criteria. Table 6 gives the synthesized priorities of costs criteria.

Table 5. Pairwise comparisons and priorities of costs control criteria

	Political	Societal	Economic	Technological	National	Priorities
Political	1	1/4	1/5	1/7	1/9	0.0724
Societal	4	1	1/3	1/2	1/4	0.1529
Economic	5	3	1	2	1/3	0.4247
Technological	7	2	2	1	1/4	0.0369
National	9	4	3	4	1	0.3132

Table 6. Costs priorities

Goal - Costs Control Criteria Hierarchy	Normalized By Cluster	Limiting Priorities
C1 Political	0.0724	0.0275
C11 International	0.7500	0.0206
C111 Bargaining Power	0.2000	0.0041
C112 Foriegn Political Backlash	0.8000	0.0165
C12 Domestic - Special Interest Groups	0.2500	0.0069
C121 Environmental	0.8334	0.0057
C122 Business	0.1666	0.0011
C2 Societal	0.1529	0.0581
C21 Sense of Well Being	0.8750	0.0508
C211 Petroleum products	0.0607	0.0031
C212 Coal	0.0312	0.0016
C213 LNG	0.0646	0.0033
C214 Natural Gas	0.0208	0.0011
C215 Hydrogen Economy	0.4926	0.0250
C216 Nuclear	0.1870	0.0095
C217 Renewables	0.1431	0.0073
C22 Short term consumer cost increase	0.1250	0.0073
C3 Economic	0.4247	0.1614
C31 Domestic	0.8333	0.1345
C311 Domestic Employment Loss	0.8000	0.1264
C312 Domestic Grid Instability	0.2000	0.0316
C32 International	0.1667	0.0269
C321 International Exports	0.6667	0.0022
C322 International Trade/Tariffs/Sanctions	0.3333	0.0011
C4 Technological	0.0369	0.0140
C41 Domestic R&D Costs	0.0433	0.0006
C42 Domestic Deployment Costs	0.3055	0.0043
C43 Domestic Transition Costs	0.5273	0.0074
C44 International Trade Costs	0.1239	0.0017
C5 National Security	0.3132	0.1190
C51 Increased Terrorism	0.1111	0.0132
C52 Oil Peaking	0.8889	0.1058

Risks Model

The risks sub-network illustrated in Figure 5 has five alternative sub-networks in its nodes (R13, R32, R341, R346 and R41). It is interesting is that in every instance Oil Peaking has a high priority, both in the costs and risks sub-networks.

The matrix illustrated in Table 7 shows the cluster pairwise comparison values for the risks control criteria. Table 8 gives the synthesized priorities of the risks criteria.

Table 7. Pairwise comparisons and priorities of risks control criteria

	Energy Policy	Technological	Environmental	Economic	Priorities
Energy Policy	1	4	2	1	0.3620
Technological	1/4	1	1/3	1/5	0.0767
Environmental	1/2	3	1	1	0.2385
Economic	1	5	1	1	0.3219

Table 8. Risks priorities

Goal - Risks Control Criteria Hierarchy	Normalized By Cluster	Limiting Priorities
R1 Energy Policy Failure	0.1244	0.0559
R11 International Backlash	0.0598	0.0033
R12 Domestic Instability	0.1606	0.0090
R13 Economic Calamity	0.4723	0.0264
R14 Society	0.2275	0.0127
R15 National Security Compromised	0.0799	0.0045
R2 Technological	0.0606	0.0272
R21 Fuel Choice	0.7306	0.0199
R211 Petroleum products	0.0444	0.0009
R212 Coal	0.0286	0.0006
R213 LNG	0.1679	0.0033
R214 Natural Gas	0.0432	0.0009
R215 Hydrogen Economy	0.4307	0.0086
R216 Nuclear	0.2585	0.0051
R217 Renewables	0.0268	0.0005
R22 Research and Development	0.0810	0.0022
R23 Infrastructure	0.1884	0.0051
R3 Environmental	0.3015	0.1355
R31 Increased Emissions	0.0926	0.0126
R32 Political	0.1889	0.0256
R33 Health	0.1188	0.0161
R34 Fuel Choice	0.5996	0.0813
R341 Petroleum Products	0.2871	0.0233
R342 Coal	0.2499	0.0203
R343 LNG	0.0707	0.0057
R344 Natural Gas	0.0497	0.0040
R345 Hydrogen Economy	0.0473	0.0038
R346 Nuclear	0.2686	0.0218
R347 Renewables	0.0269	0.0022
R4 Economic	0.5135	0.2308
R41 Oil Peaking	1.0000	0.2308

BOCR/Alternative Analysis

Table 9 shows how the alternatives were ranked for benefits, opportunities, costs and risks. The benefits and opportunities models rank the Energy Independence Emphasis the highest followed by Complete Energy Independence. For the costs model, the Comparative Advantage Approach was the most costly. Interestingly, the other three alternatives were very close in rating. This suggests that all three have about the same level of costs and are interchangeable in a decision as far as costs are concerned. The results of the risks model show the Comparative Advantage Approach to be the most risky followed by Complete Energy Independence.

Table 9. Ranking of alternatives for BOCR

Alternatives	Benefits (0.3260)	Opportunities (0.3323)	Costs (0.0828)	Risks (0.2588)
1 Status Quo Energy Policy	0.5228	0.2733	0.3569	0.4448
2 Energy Independence Emphasis	0.7989	0.9541	0.3503	0.4663
3 Complete Energy Independence	0.5815	0.6725	0.3649	0.6430
4 Comparative Advantage Approach	0.3841	0.2985	0.9040	0.8204

To synthesize the benefits, opportunities, costs and risks, they are rated as clusters with respect to three strategic control criteria: Energy Security, International Competitiveness and Environmental Quality. Their priorities of the strategic criteria are given in Table 10.

Table 10. Ratings and Priorities for BOCR with respect to Strategic Criteria

	Energy Security 0.625	International Competitiveness 0.238	Environmental Quality 0.137	Priorities
Benefits	High	High	Low	0.3260
Opportunities	High	High	Low	0.3323
Costs	Moderate	Moderate	Low	0.0828
Risks	High	Moderate	Low	0.2588
Intensities:	High 1.0000	Moderate 0.2404	Low 0.1154	

Table 10 also shows the final priorities of benefits, opportunities, risks and costs after the ratings are translated into a numerical scale. Benefits and opportunities are rated as the most significant of the merits.

4. MODEL RESULTS

The synthesized results of the entire model, taking into account the weighting factors of the strategic rating model discussed in Section 2, are given in Table 11. The results indicate that the U.S. energy policy should be strongly

driven toward an Energy Independence Emphasis. This alternative was perceived to be twice more effective than the alternative Complete Energy Independence and almost three times more than the Status Quo. The Comparative Advantage Approach lagged the other three alternatives and should never be considered as an energy policy option.

Table 11. Synthesized priorities

	Synthesis	
Alternatives	BO/CR	bB+oO-cC-rR
1 Status Quo Energy Policy	0.9000	0.1166
2 Energy Independence Emphasis	4.6663	0.4278
3 Complete Energy Independence	1.6666	0.2164
4 Comparative Advantage Approach	0.1546	-0.0628

5. SENSITIVITY ANALYSIS

A sensitivity analysis was performed to determine if the overall results illustrated in Table 11 would vary due to the judgments made in the model. This section will look at each of the main control criteria identified as the benefits, opportunities, costs, and risks associated with the goal of the energy security of the U.S.

Benefits

The benefits sensitivity analysis illustrated in Figure 9 indicates that the greatest benefits will always be achieved through Alternative # 2, Energy Independence Emphasis. Alternative # 2 is followed by Alternative # 3, Complete Energy Independence, which is two orders of magnitude and at times three orders of magnitude less significant than Alternative # 2. Alternative # 1, Status Quo Approach, does not present itself as providing any benefit until after a 15% emphasis on the benefits related to the energy security of the U.S. is considered. The comparative advantage approach, Alternative # 4, begins to provide positive benefits after 40% emphasis on the benefits related to the energy security issue is considered but at this point Alternative # 2 is at its highest benefit potential of 60%. This point is captured in the following figure by the dashed vertical line.

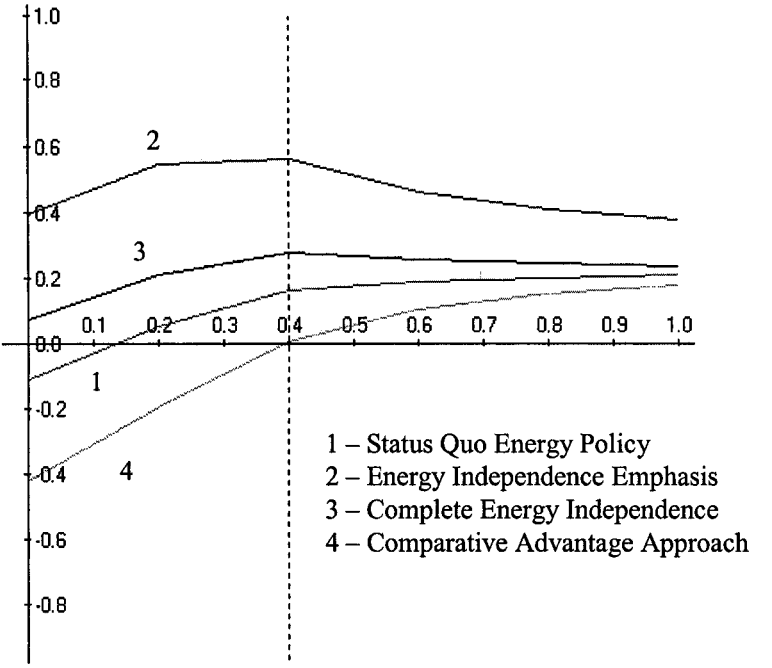

Figure 9. Benefits Sensitivity Analysis

Opportunities

The Opportunities sensitivity analysis illustrated in Figure 10 indicates that the greatest opportunities will be present through Alternative # 2, Energy Independence Emphasis. This alternative with a priority value of 0.562 is followed by Alternative # 3, Complete Energy Independence, with priority equal to 0.284 when there is a 40% emphasis associated to the opportunities with respect to the energy security of the U.S.. The Status Quo Approach, Alternative # 1, does present higher opportunity potential compared to Alternative 3 below a 10% emphasis. Above a 10% emphasis it levels out from a 5% to 10% opportunity potential. Likewise, Alternative # 3 increases from a 5% to a 30% opportunity potential at the extreme emphasis scenario.

The Comparative Advantage Approach, Alternative # 4, begins to provide positive opportunities after a 40% emphasis on the energy security issue is considered but at this point Alternative # 1 is at it highest opportunity potential of 60%. This point is similar to the benefits sensitivity analysis and is captured in the following figure by the dashed vertical line.

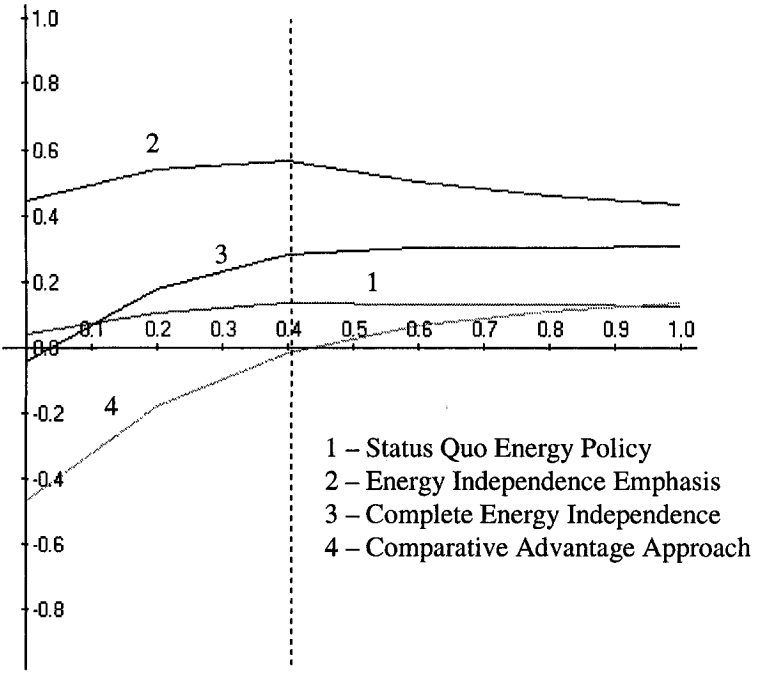

Figure 10. Opportunities Sensitivity Analysis

Costs

The Costs sensitivity analysis illustrated in Figure 11 indicates that the greatest costs will be present through Alternative # 4, Comparative Advantage Approach, at any given emphasis or judgment. The next costly alternative is, Status Quo Approach which is followed by Complete Energy Independence. This leaves the least costly alternative as the Energy Independence Emphasis. As Figure 53 indicates that not until an emphasis greater than 60% is considered will Alternative # 2's cost enter a negative range, but still the least cost when compared to the other three alternatives.

What is also interesting in the figure below is that when a cost is the primary emphasis when considering the direction for the energy security of the United States, Alternatives 1-3 converge but are still significantly less costly than Alternative #4, Comparative Advantage Approach.

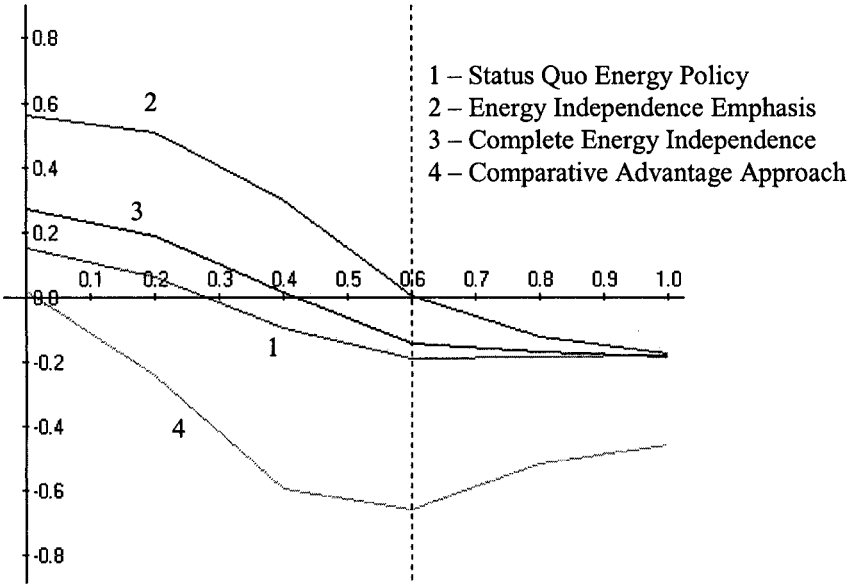

Figure 11. Costs Sensitivity Analysis

Risks

The Risks sensitivity analysis illustrated in Figure 12 indicates that the greatest risks will be present through Alternative # 4, Comparative Advantage Approach, at any given emphasis or judgment. The Status Quo Approach follows as the next riskier alternative until a 53% emphasis is considered where it changes ranking with the Complete Independence Alternative. Alternative # 2 once again shows to be the best option or creating the least risk.

Another convergence point is illustrated when risk concerns are paramount to benefits, opportunities, and cost. That convergence is between Alternative # 1, Status Quo Approach, and Alternative # 2, Energy Independence Emphasis.

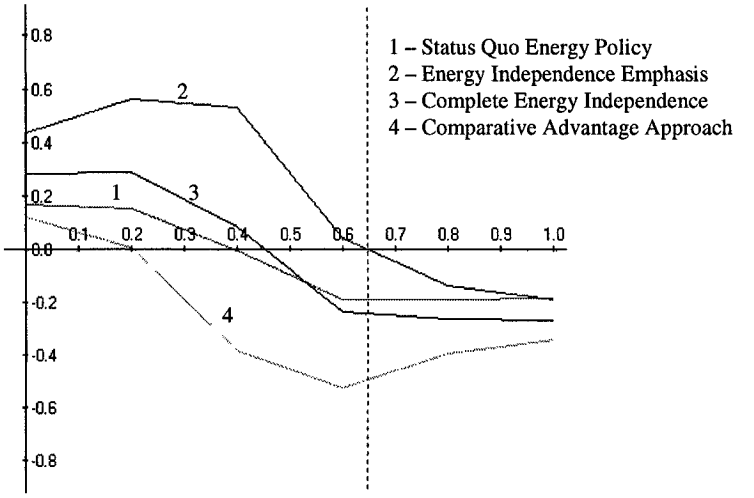

Figure 12. Risks Sensitivity Analysis

Considering the benefits, opportunities, costs and risks all at once the graph of the sensitivity analysis (Figure 13) shows that Alternative #2 consistently dominates all others under all possible combinations of changes in the priorities.

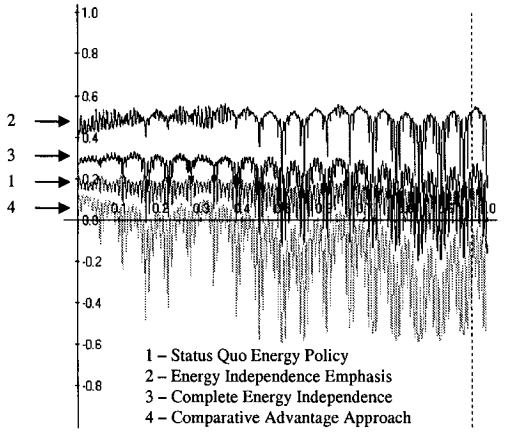

Figure 13. BOCR Sensitivity Analysis

6. CONCLUSION

Deciding the direction of the U.S. energy policy to ensure its energy security is a very complex issue with many influences on how that decision will turn out. As the model demonstrated that many of the forces that we would consider as important are not that significant in the grand scheme. They do play a part on how the true drivers or motivators for one alternative versus another is decided so they should not be rapidly dismissed.

Table 11 shows that an Energy Independence Emphasis should drive the energy policy of the U.S. and intuitively that is the answer that we would have chosen. It created the greatest benefits and opportunities while generating the least costs and risks when considered against the multitude of criteria we modeled.

The Status Quo Approach was ranked 3rd and 4th for benefits and opportunities, respectively, and it was also ranked 3rd and 4th least for costs and risks, respectively. This makes sense since this alternative has an order of flexibility but in the long run it is not the best alternative with regard to an energy policy direction.

The alternative Complete Energy Independence is twice as significant as the Status Quo Approach with respect to benefits and opportunities and ranked the 2nd highest in cost and risk. The costs associated with converting the entire energy infrastructure to be run from domestic resources would and most likely bankrupt the country. In addition, the isolationism that would be perceived by the global community could increase the risk of terrorism and trade sanctions and tariffs against the U.S.

In every instance the Comparative Advantage Approach is the worst alternative for the U.S. It has the highest costs and risks while providing the least benefits and opportunities.

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CHAPTER 9

STABILIZING SOCIAL SECURITY FOR THE LONG-TERM

Valorie Checque, Larry E. Nolph and Brian R. Patt
(Spring 2005)

1. INTRODUCTION

President Roosevelt founded Social Security in 1935. In 1937, the Federal Insurance Contribution Act (FICA) was signed and mandated that workers contribute 2 percent of wages.

Over the next sixty-eight years, FICA has been amended numerous times including eight increases to the withholding percentage, which currently stands at 12.4%. Cost of Living Adjustments (COLA) were added first in 1972 and revised in 1977.

In the early 80s, the system was declared actuarially unsound. The National Commission on Social Security Reform was founded and in 1983 called for:

1) an increase in the self-employment tax partial taxation of benefits to upper income retirees
2) expansion of coverage to include federal civilian and nonprofit organization employees
3) An increase in the retirement age from 65 to 67, to be enacted gradually starting in 2000.

Again, Social Security was declared actuarially unsound. Of course, this declaration was premature as the Social Security Trustees' Report of 1996 stated that the Social Security system would start to run deficits in 2012, and the trust funds would be exhausted by 2029. All members of the Advisory Panel agreed that some or all of Social Security's funds should be invested in the private sector. To keep the unchanged system actuarially sound, payroll taxes would have to be increased 50%, to 18% of payroll, or benefits would have to be slashed by 30%. In 1997, all members of the presidential-appointed Social Security Advisory Panel agreed that some or all of Social Security's funds should be invested in the private sector. They also concurred with the Social Security Trustee's Report that in order to keep the unchanged system actuarially sound, payroll taxes would have to be increased 50%, to 18% of payroll, or benefits would have to be slashed by 30%."

In the eight years since the advisory panel's recommendation, little has been done to correct the issue only exacerbating the size and scope of the problem. President George W. Bush has put the issue at the forefront of his agenda for the second term with his proposal to privatize a portion of the program.

Responses to the President's proposal range from acceptance, to labeling it as a retrenchment back to the days before Social Security. Moreover, some groups say the problem is overstated, that Social Security only requires minor modifications. The goal is to use ANP (Figure 1) to determine the best available option for stabilizing Social Security over the long-term.

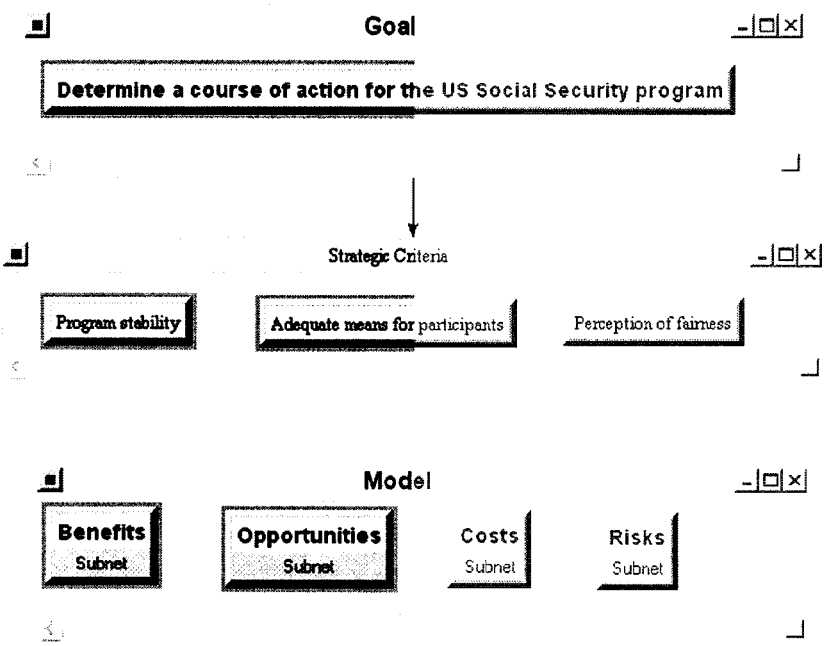

Figure 1. Strategic Criteria and BOCR Model

2. STRATEGIC CRITERIA

Tree strategic criteria were identified to be used when assessing any proposed alternative; they are Program Stability, Adequate Means for Participants, and Perception of Fairness.

Program Stability – Program stability suggests that there is a program in place, long-term for all participants. The optimal solution should ensure that the program survives and does not need further significant modifications. Participants should have peace of mind that when they retire, the program will be there throughout their lifetime.

Adequate Means for Participants – Participants should be able to rely on prescribed level of benefits that are adequate to support participants in their

retirement. A stable program that pays some insignificant level of benefits is not considered optimal.

No attempt was made to define what that prescribed level of benefits is. Social Security was originally intended to be a supplement to a retiree's other income. The retiree was also to have a company pension as well as personal savings to rely upon. Over time, there has been an increase in retirees' reliance on Social Security. At the program's inception through the forties Social Security only comprised approximately 20-25% of a retiree's income. Today, retirees rely on Social Security for 67% of their income on average. Years of low personal savings levels and pension failures have increased the strain on the Social Security system.

Perception of Fairness – Whatever the solution, the program needs to be perceived as a fair system. One segment of the population should not be seen as benefiting unfairly from any proposed changes.

3. ALTERNATIVES

Fourteen alternatives were considered initially. However, there are overlaps in some, while others were considered not viable. This list of fourteen was then narrowed to five alternatives. They are:

Raise Ceiling – This alternative proposes raising the level of income subject to the 12.4% Social Security withholding. Currently, any income above $90,000 is not subject to Social Security withholding. The cap on the withholding level can be increased as a one-time adjustment, or over a series of years. A more draconian approach would be to remove the cap completely. An increase in the withholding percentage for all participants was also examined. In the current environment, this revenue-enhancing alternative appears to be much more likely.

Raise Retirement Age – The normal retirement age has been raised in the past and this option is considered viable in the current situation. Life expectancy of Americans continues to increase. The tendency causes the ratio of years as a payer to years as a payee to change. As the ratio increases, it places increasing strain on the financial resources of the system. All other factors held constant, the system will either need to find another mechanism to increase revenue or to decrease expenditures.

Privatize – While there are numerous possible scenarios, the proposal by President Bush where certain participants can elect to have 4% of their wages diverted to a private investment account is used. Lower and higher percentages have been proposed, but it is believed that this proposal has received adequate scrutiny and analysis to enable one to make an informed opinion as to its benefits, opportunities, costs, and risks.

Reduce Benefits – This alternative can encompass a broad array of tactics. The mechanics used to reduce benefits could be the subject of another model if this alternative is deemed optimal. Among the choices are a simple one-time cut in benefit, a temporary freeze in benefit levels, or a reduction in future COLA adjustments. The main theme is a method of expenditure control vs. revenue enhancing ideas such as *"Raising the Withholding Ceiling"*.

Status Quo – This alternative says to leave the Social Security program as it is. There should be no modifications to the system. Proponents of this alternative believe that the current system does not require fixing, and that some external influences will arise to correct the current deficit. While the vast majority of people would agree that some level of correction is required, this alternative was also included because of the tendency to neglect or delay dealing with the problem. The current issues were first identified back in 1996 and have yet to be addressed in any form. History might suggest this as an alternative, no matter how ill-advised.

4. BENEFITS/OPPORTUNITIES/COSTS/RISKS

OVERVIEW

The benefits, opportunities, costs and risks models share the same control criteria. They are: Social, Political, and Economic. The subnets within each, however, may differ depending on the control criterion. Figure 2 shows a sample Control Criteria Hierarchy

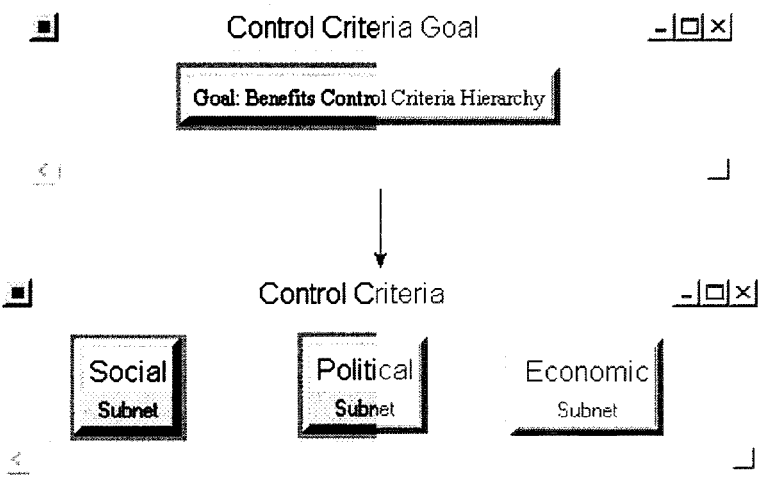

Figure 2. Hierarchy of Benefits Control Criteria

BENEFITS

The Social Subnet (Figure 3) has two elements within the Stakeholders' Cluster:

- Payee Confidence - confidence of those receiving benefits that their benefits will continue at an acceptable rate
- Payer Confidence - confidence of those paying in to the program that it is worthwhile and they would see a return on the money they are investing

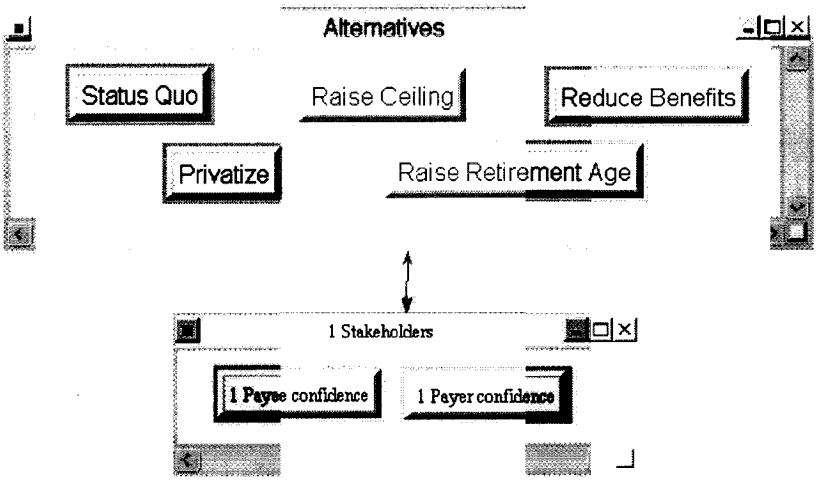

Figure 3. Social Subnet

The Political subnet (Figure 4) contains two clusters, President and Legislative:

President

- Media Coverage – the benefit that comes from positive coverage in media outlets.
- Voter Perception – the benefit that comes from a favorable impression in the mind of likely voters.
- Legacy Place in History – the benefit that comes from being identified with significant historical achievements.

Legislative

- Media Coverage – the benefit that comes from positive coverage in media outlets.
- Party Recognition - supporting the alternative results in support or lack of support from the legislator's political party
- Voter Perception – the benefit that comes from a favorable impression in the mind of likely voters.

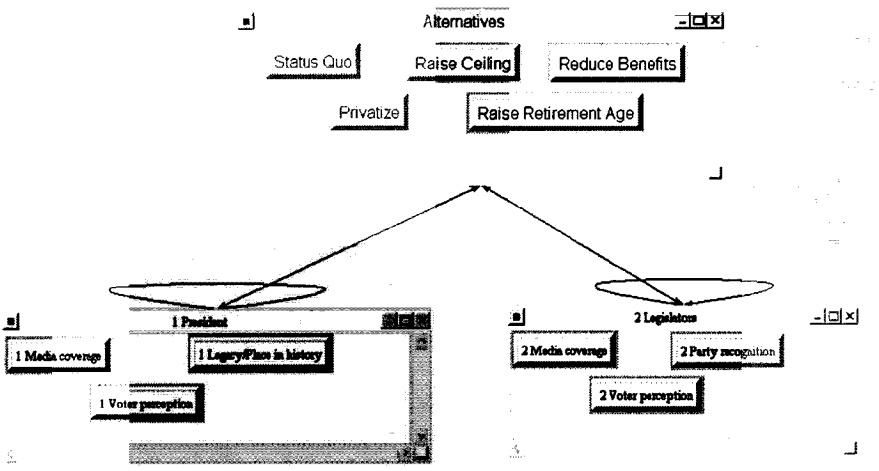

Figure 4. Political Subnet

The Economic subnet (Figure 5) contains only one cluster, the Financial cluster. This cluster contains two nodes

- Program Stability – Program that is not overly susceptible to normal political or economic fluctuations.
- US Economic Stability – Program that does not subject the economy to fluctuations or inhibit growth.

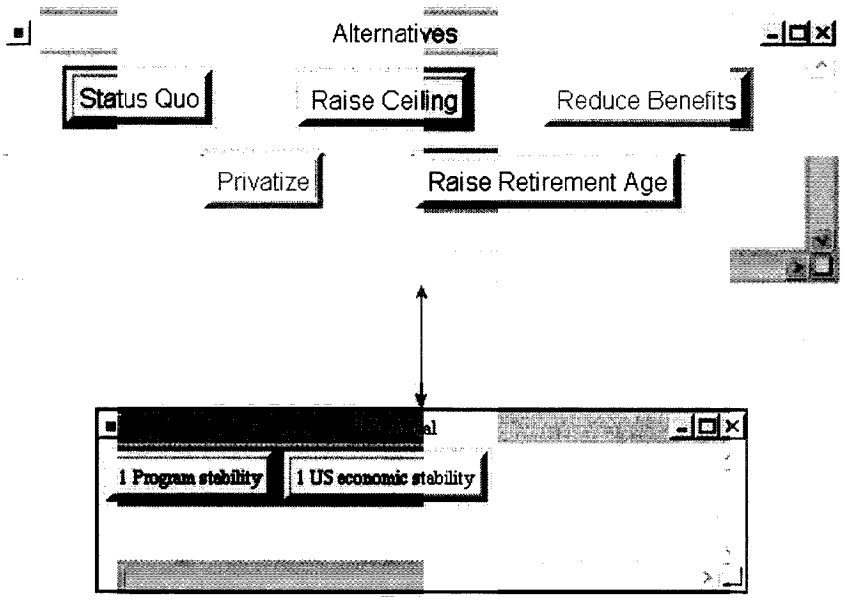

Figure 5. Economic Subnet

OPPORTUNITIES

The Social Subnet (Figure 6) has three elements within the Stakeholders Cluster:

- Participant Peace of Mind – comfort that comes from the assurance that the program will last throughout the participant's lifetime.
- Encourage Financial Responsibility – encourages participants to educate themselves on financial matters.
- Decreased Dependence on Government Programs – potential benefit that comes from a more secure financial future where participants increase personal savings rates.

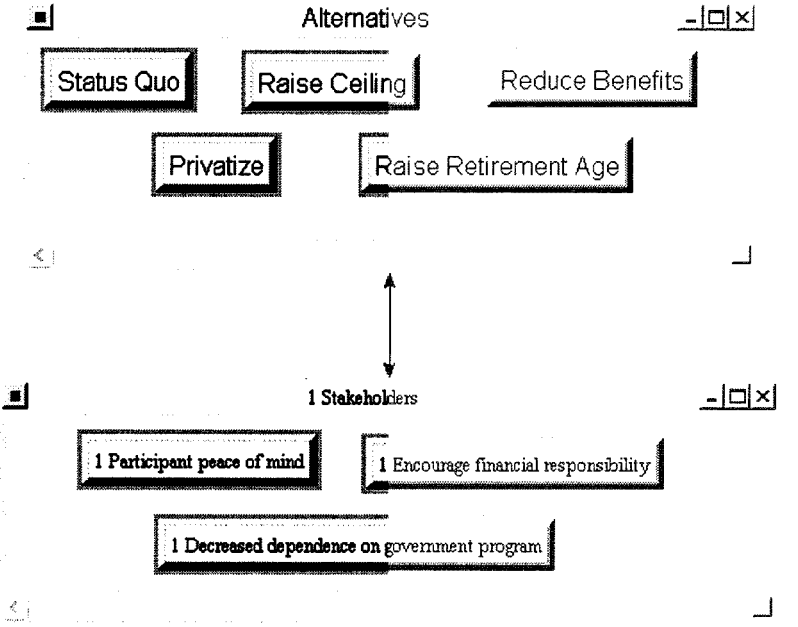

Figure 6. Social Subnet

The Political subnet (Figure 7) contains two clusters, President and Legislative:

President

- Media Coverage – the benefit that comes from positive coverage in media outlets.
- Attract New Supporters – the potential benefit from taking a position that brings in likely voters outside the normal base.
- Increased Political Capital – the potential benefit that comes from securing a major political victory that translates into more political power on upcoming issues.
- Legacy Place in History – the benefit that comes from being identified with significant historical achievements.

Legislative

- Media Coverage – the benefit that comes from positive coverage in media outlets.
- Party Recognition - supporting the alternative results in support or lack of support from the legislator's political party
- Attract new supporters – the potential benefit from taking a position that brings in likely voters outside the normal base.
- Likelihood of re-election – increase in the likelihood of re-election from association with a significant political issue.

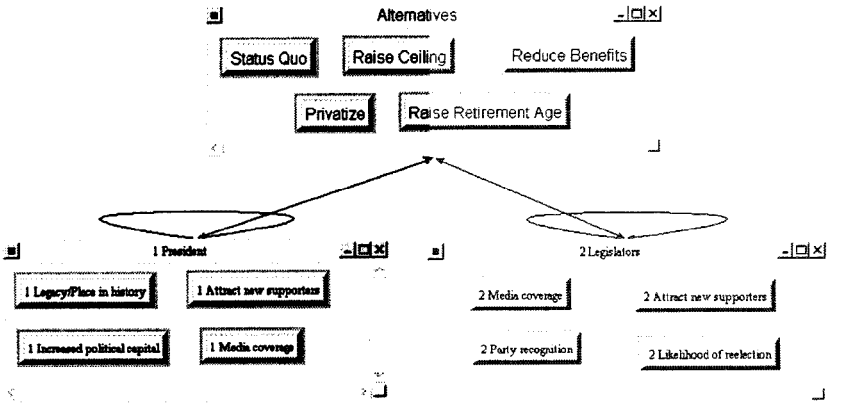

Figure 7. Political Subnet

The Economic subnet (Figure 8) contains two clusters, Financial and Operational:

Financial

- Effect on Capital Markets –the potential benefit on interest rates or investment rates from the alternative.
- Effect on US Budget – the potential positive impact on the US budget deficit.
- Effect on US Economy – the potential opportunity from for positive impact to the US Economy.

Operational

- Reduction of Bureaucracy – the potential impact of a reduction in US government bureaucracy and/or a reduction of bureaucracy at employers to comply with the program.

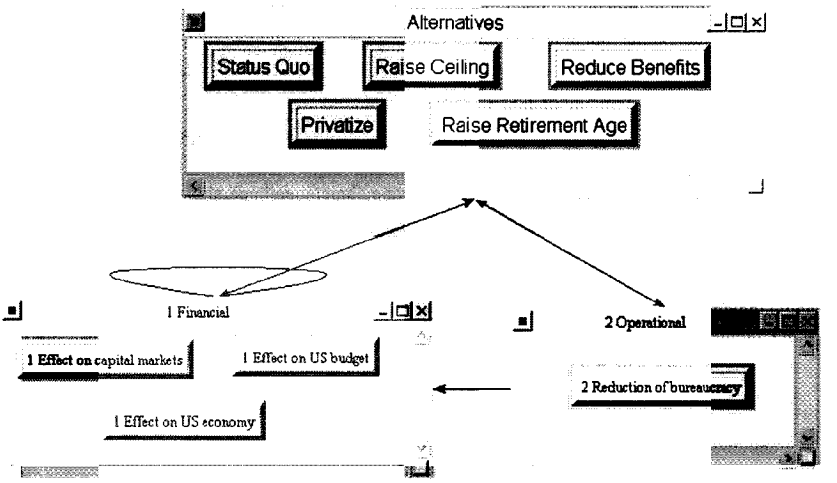

Figure 8. Economic Subnet

COSTS

The Social subnet (Figure 9) has three elements within the Stakeholders Cluster:

- Fees – the amounts paid by participants to third parties to have individual accounts managed.
- Increased withholding – the cost to participants through increased withholding in a given year.

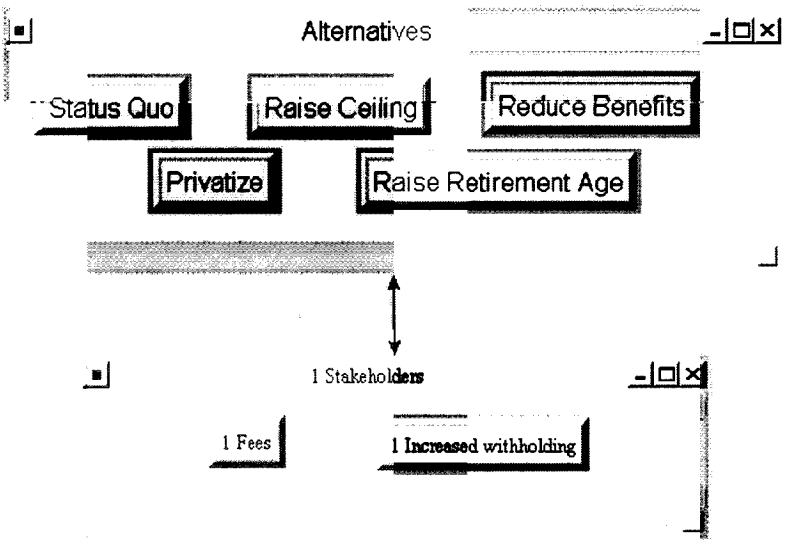

Figure 9. Social Subnet

The Political subnet (Figure 10) contains only the Legislative cluster with one node:

- Constituent Alienation – the likelihood that efforts on an alternative would anger or disenfranchise constituents.

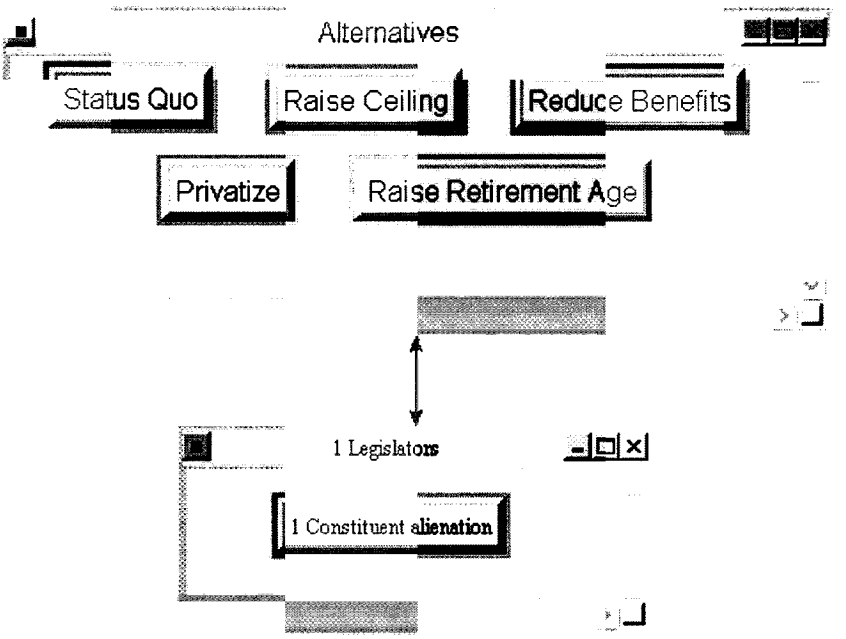

Figure 10. Political Subnet

The Economic subnet (Figure 11) contains one cluster, the Operational cluster:

Operational

- Conversion Costs – one-time costs to implement the alternative.
- Agency Costs – ongoing costs necessary to implement the alternative.
- Marketing/Communication to Public – costs to ensure that the general public understands the alternative sufficient to plan appropriately.

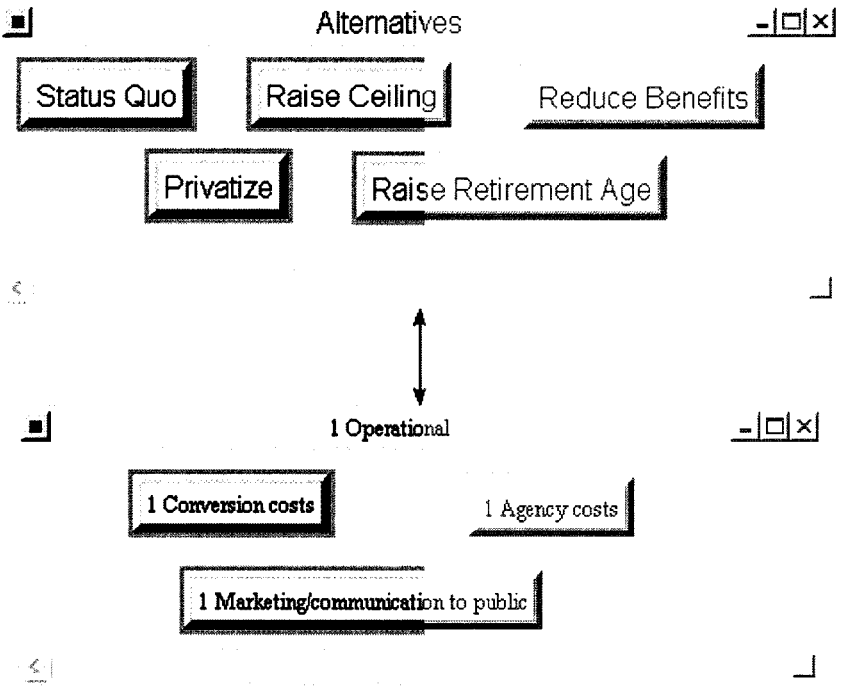

Figure 11. Economic Subnet

RISKS

The Social subnet (Figure 12) has three elements within the Stakeholders' Cluster:

- Payee Confidence - confidence of those receiving benefits that their benefits will continue at an acceptable rate
- Payer Confidence - confidence of those paying in to the program that it is worthwhile and they will see a return on the money they are investing
- Increased Potential for Profit – potential that an alternative will lead to higher rate of return on investment.
- Loss of Potential Profit – opportunity cost of not pursuing a different alternative
- Reduced Benefits – risk that an alternative will lead to a reduction in benefits.

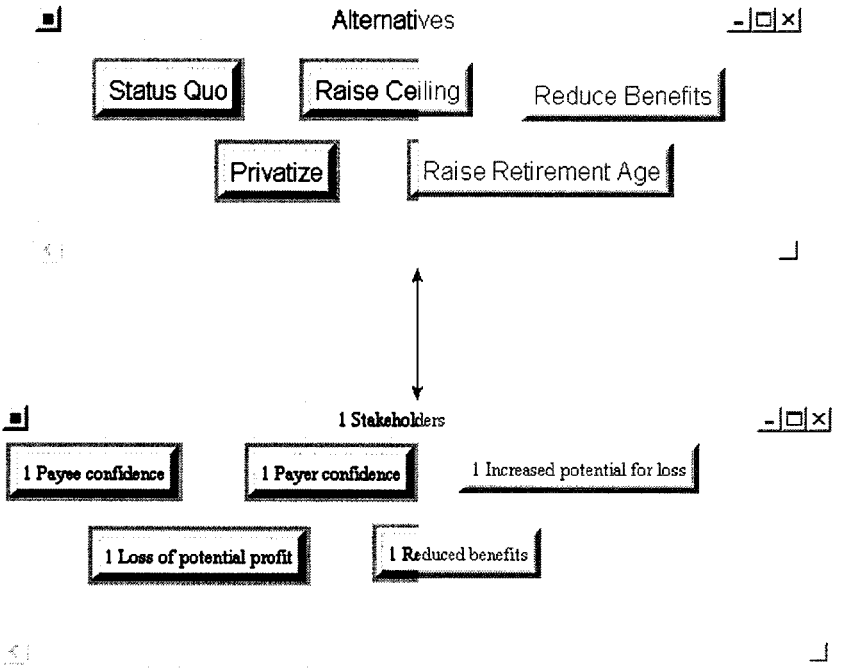

Figure 12. Social Subnet

The Political subnet (Figure 13) contains two clusters, President and Legislative:

President

- Constituent Alienation – the likelihood that efforts on an alternative would anger or disenfranchise constituents.
- Legacy Place in History – benefit that comes from being identified with significant historical achievements.
- Media Coverage – benefit that comes from positive coverage in media outlets.
-

Legislative

- Constituent Alienation – the likelihood that efforts on an alternative will anger or disenfranchise constituents.
- Likelihood of re-election – increase in the likelihood of re-election from association with a significant political issue.
- Media Coverage – benefit that comes from positive coverage in media outlets.
- Party Recognition - supporting the alternative results in support or lack of support from the legislator's political party

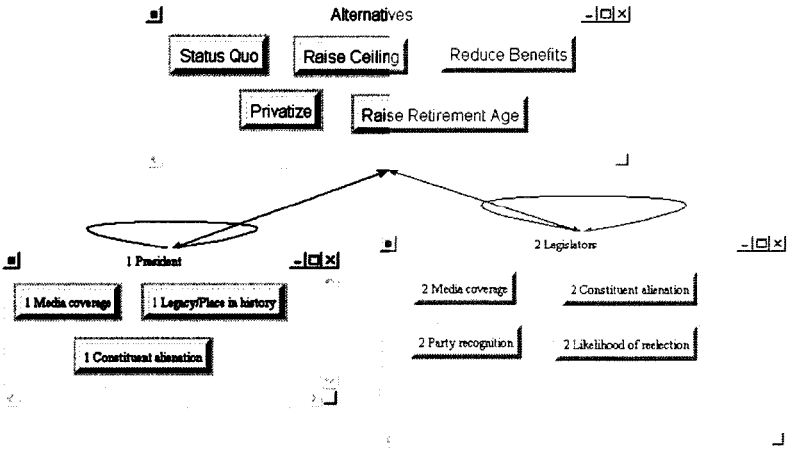

Figure 13. Political Subnet

The Economic subnet (Figure 14) contains two clusters, Financial and Operational:

Financial

- Long-term Insolvency – risk that an alternative would lead to or contribute to the insolvency of the program.

Operational

- 3rd Party Failure – risk that a non-government agency associated with the program would experience bankruptcy.
- Increased Corruption – risk that the alternative would lead to increased abuse or corruption.

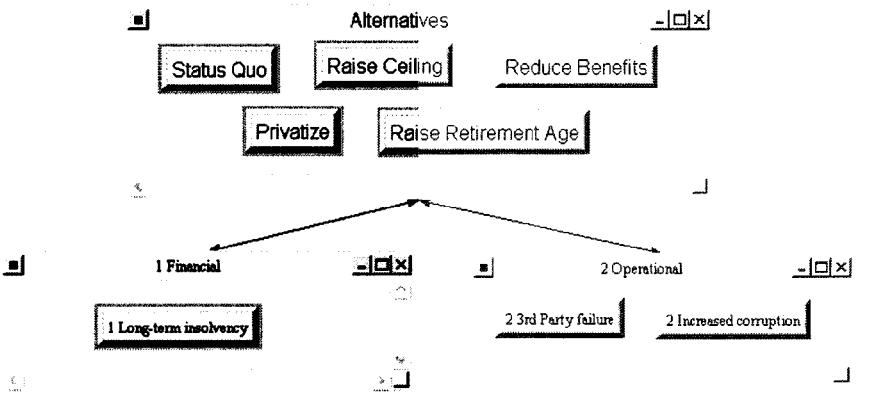

Figure 14. Economic Subnet

5. RESULTS

To synthesize the priorities of the alternatives from the benefits, opportunities, costs and risks, we first need to rate the BOCR subnets according to the strategic criteria. Using the scale of intensities given in the last row of Table 1, we rate the benefits, opportunities, costs and risks by first selecting the best alternative under each subnet and score it for each strategic criterion. The results are then weighted by the priorities of the strategic criteria. The priorities of the alternatives from each subnet (Figures 3-14) are given in Table 2. The synthesized priorities of the alternatives for benefits, opportunities, costs and risks in ideal form are given in Table 3. The normalized results (column 3 of Table 1) are the priorities used to synthesize the priorities of the alternatives (Table 3).

Table 1. BOCR Ratings

	Adequate Means for Participants *0.2684*	Perception of Fairness *0.1172*	Program Stability *0.6144*	Normalized Priorities
Benefits	High	Low	High	0.3885
Opportunities	Low	Low	Medium	0.1847
Costs	High	Medium	Medium	0.2791
Risks	Medium	Low	Low	0.1477

Intensities:	Very High	High	Medium	Low	Very Low
	1.0000	0.5684	0.3026	0.1595	0.0927

Table 2. Priorities of the alternatives from each subnet in the BOCR model

	Benefits			Opportunities			Costs			Risks		
Control Criteria →	Social	Political	Economic	Social	Political	Economic	Social	Political	Economic	Social	Political	Economic
Alternatives	0.2857	0.1429	0.5714	0.4000	0.2000	0.4000	0.5278	0.1396	0.3325	0.6250	0.1365	0.2385
Privatize	0.7851	0.4268	0.4552	1.0000	1.0000	0.8541	0.8856	0.2852	1.0000	0.4621	0.3214	0.4820
Raise Ceiling	1.0000	1.0000	0.4377	0.5143	0.8814	0.4131	0.6019	0.1230	0.0929	0.2374	0.1362	0.7574
Raise Retirement Age	0.9742	0.6289	0.9127	0.5329	0.5296	0.5642	1.0000	0.3009	0.0929	0.3730	0.2283	0.5331
Reduce Benefits	0.5484	0.1956	1.0000	0.4223	0.1724	1.0000	0.3186	1.0000	0.2620	1.0000	1.0000	0.2647
Status Quo	0.5830	0.3640	0.2474	0.2607	0.3499	0.3039	0.3186	0.1759	0.0929	0.4125	0.3674	1.0000

Table 3. Synthesized Priorities of Alternatives in ideal form under BOCR

	Benefits	Opportunities	Costs	Risks		
Alternatives	0.3885	0.1847	0.2791	0.1477	BO/CR	bB+oO-cC-rR
Privatize	0.5454	0.9417	0.8398	0.4477	1.3661	0.0853
Raise Ceiling	0.6787	0.5473	0.3657	0.3476	2.9213	0.2113
Raise Retirement Age	0.8898	0.5448	0.6007	0.3914	2.0613	0.2208
Reduce Benefits	0.7561	0.6034	0.3949	0.8246	1.4008	0.1731
Status Quo	0.3599	0.2958	0.2236	0.5464	0.8715	0.0513

The synthesis of the individual subnets (Table 3) indicates that Raising the Retirement age provides the highest benefits. This is likely due to the fact that it both reduces expenditures as well as raises revenue. Privatization provides the

most upside opportunity related to the potential for increased returns from investing in the capital markets.

Turning to costs, Privatization also brings with it the highest costs (Table 3). Privatization would have the highest conversion and agency costs as well as any fees associated with maintaining individual personal accounts. Reducing Benefits yields the highest risks (Table 3). The political backlash associated with such a widely unpopular alternative is significant.

6. SENSITIVITY ANALYSIS

Except at low levels (below 0.20), the model is relatively insensitive to changes in the priority of Benefits. Raising the Retirement Age consistently delivers more benefits.

Below approximately 0.28, Raising the Retirement Age has the highest Opportunity. Above a priority of 0.28, Privatization yields the highest opportunity (Figure 15).

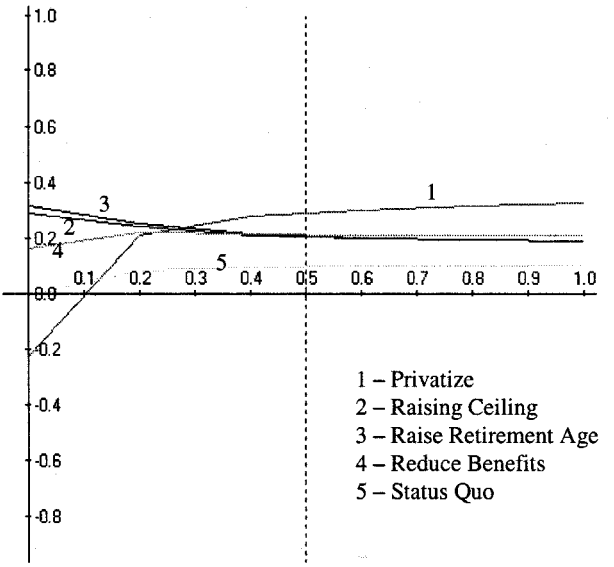

Figure 15. Sensitivity Analysis of Opportunities

When examining the sensitivity to Costs, Privatization consistently yields the highest costs. Raising the Ceiling and Maintaining the Status Quo share the lowest cost at various degrees of priority (Figure 16).

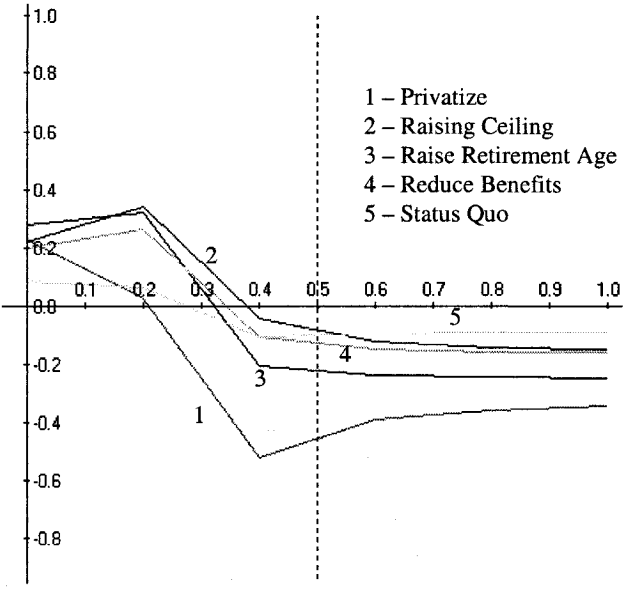

Figure 16. Sensitivity Analysis of Costs

Raising the Ceiling and Raising the Retirement Age nearly share the lowest risk. Reducing Benefits and Maintaining the Status Quo share the highest risks at differing levels of priorities (Figure 17).

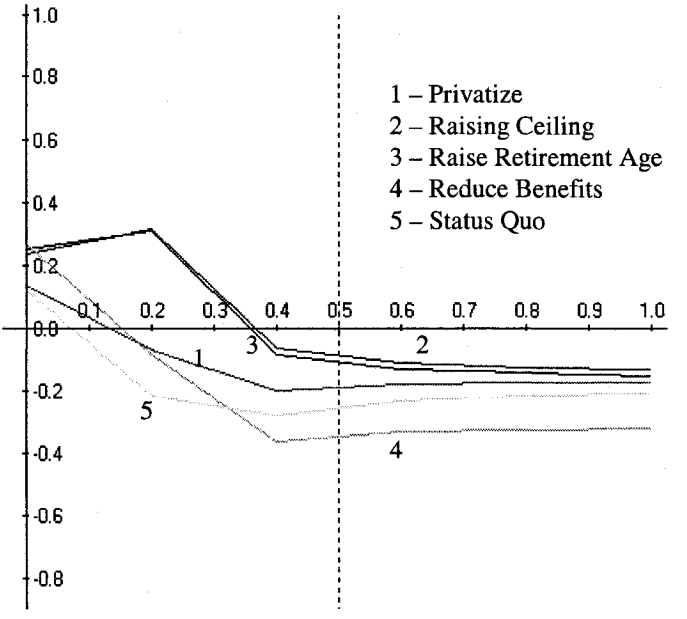

Figure 17. Sensitivity Analysis of Risks

7. CONCLUSION

Among the major factors influencing the results are:

- Approximately 90% of all wages were subject to Social Security withholding in 1980; by 2004, that percentage had slipped to 85%.
- In 1935, Social Security was designed to support older Americans who were dependent and beyond their productive period, originally calculated to begin at age 65, when men had an average of 12 years ahead of them.
- Today, a 65-year-old man can expect to live for 17 more years (women, 20) – 5 years longer than original budget estimates. A system designed for men with 12 years ahead of them today would set the retirement age between 70 and 75

Given the relative scores under the additive model and the sensitivity analysis, the Raise the Ceiling and Raise the Retirement Age alternatives are almost identical in every respect, leaving each or a combination of the two as the optimal alternatives.

APPENDIX SCHEDULES

ALTERNATIVE DETAIL

Below is the detail of the original fourteen alternatives that were identified and the rationale for either including or excluding the alternative in the final ANP model.

Raise Tax Rate – While not specifying a specific amount, this alternative proposes increasing the withholding percentage for all participants from the current level of 12.4%. This alternative was not included in the final model do to nearly non-existent support to the idea.

Raise Retirement age – The normal retirement age has been raised in the past and this option is considered viable in the current situation. The life expectancy of Americans continues to increase. The current normal retirement age ranges from 65-67 years of age. This alternative is included in the final model.

Eliminate Maximum WH income – This would eliminate the current ceiling on wages that are subject to Social Security withholding. This alternative was included in the final model but was modified to say increase the ceiling.

Reduce Benefits – This is a one time global reduction in benefits. The formula for calculating benefit levels would be reduced. This alternative is in the final model, but is revised to more-broadly incorporate any mechanism that reduces benefits such as temporary freezes on increases, broad benefit level cuts, or a reduction in COLA levels.

Freeze Benefits – This alternative suggests freezing the level of benefits for some period of time, rather than forcing people to deal with a benefit cut. It was deemed more practical than an outright reduction in benefits. This alternative was combined into a broader reduce benefits alternative in the final model.

Cut COLA formula – Rather than reduce current benefits or freeze them for a period of time, this alternative seeks to limit the growth in benefit levels and would at first glance be to most practical of the expenditure containing alternatives. This alternative also was combined into a broader reduce benefits alternative in the final model.

Overhaul/scale back SSI disability – Support for those unable to care for themselves through disability needs to occur regardless. Elimination or reduction of these benefits would just shift to other federal/state programs such as Medicaid or Medicare. This alternative was rejected because while fixing Social Security it would exacerbate issues in other programs.

Divert 4% to Private accounts – We are using the current proposal by President Bush where certain participants can elect to have 4% of their wages diverted to a private investment account. This alternative is included in the final model.

Increase immigration – This alternative proposes an increase immigration as baby boomers retire to reduce the level of payees-to-payors ratio. This alternative was not deemed viable due the level of immigration that would be required to influence this ratio in any appreciable manner. It could be a viable part of a plan that incorporated numerous alternatives as a solution.

Subsidize SS fund by cutting spending in other programs – Given current levels of deficits and that Social Security already comprises a large portion of federal budget expenditures, this alternative in itself is not deemed to be feasible. Social Security is already by far the single large expenditure. The cuts in other programs, including Defense and Education would be too severe to make this an economically viable alternative.

Recreate "lock box" (specific SS fund unavailable to the general fund) and invest for higher returns – This alternative is essentially the same as the Divert 4% to private accounts except for who would bear the risk of loss. There is a great deal of skepticism in making the federal government such a significant force in the capital markets. The federal government in many instances would be both the regulatory body as well as the owner; such conflicts of interest have yet to be overcome. Due to its similarity to another alternative and significant issues yet to be resolved, this alternative was not included in the final model.

Base lifetime payments on lifetime contributions – This alternative suggests a link should be established between contributions and payments, moving social security closer to a 401(k) type program. This alternative was rejected because

of its potential conflict with the strategic criteria of adequate means for participants. Additionally, justification for rejection of the alternative rests in the fact that for most people age 45 and younger will not recover 100% of their contributions during their retirement. In order to achieve this alternative the benefits of retirees and soon-to-be retirees would need to be cut effective immediately and this alternative has been covered in the Reduce Benefits alternative.

Do nothing – This alternative relies on a future positive externality to resolve the current issue. It would also encompass those who believe the current problem is an overstatement or fabrication. These individuals, however minor, do exist. For periods of time, issues with Social Security have been ignored, this too makes this alternative relevant.

Phase program out – This alternative suggests that over time, the US should eliminate the Social Security program in its entirety. This alternative was not included in the final model because there is clearly no significant support for the idea. Americans do not want to potentially see a significant number of senior citizens living on below subsistence levels of income.

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CHAPTER 10

THE MOST HOPEFUL OUTCOME IN THE MIDDLE EAST CONFLICT: THE ANALYTIC NETWORK PROCESS APPROACH

Thomas L. Saaty and Hyunjoo Chang
(Summer 2002)

1. INTRODUCTION

Since the founding of Israel in 1947 and even before, there has been conflict and fighting in the Middle East. Hundreds of people including women and children have been killed and thousands injured, hundreds of homes and other properties destroyed. It is a fact that most of the dead, injured, and much of the property lost is Palestinian. Israel feels threatened by acts of terrorism and the Palestinians many of whom live in camps in Lebanon and Jordan, deprived of a national identity feel hopeless, and lacking in freedom and economic well-being. Where will this end? People have always thought that to solve the problem and create a better atmosphere, the Palestinians must have a state. There is little disagreement about that, but there is disagreement about when and what the territories of that state will be. Would that remove the hatred? It is very unlikely. What would diminish the hatred? Giving the Palestinians something constructive within the Palestinian territories like building factories there that can helps them to be profitably occupied individually and as families and groups of people. Instead of spending billions on armament, at least part of these resources along with US and international assistance should be spent on the cause of the conflict and how best to alleviate it into the distant future.

In this paper, we deal with the Middle East as a problem that affects world peace. To study the Israeli Palestinian conflict we use the Analytic Network Process, a scientific way to consider the entire complexity, interdependencies, and feedback among the elements of the conflict, and in the end, sort and identify its priorities. By ascribing judgments one knows from careful study over a long time period that the different parties have, one learns from the priorities derived from the judgments what is most likely to succeed in the face of diverse and conflicting interests and values. The most pertinent feature of this process is that it allows us to quantify intangibles based on experience, logical understanding, a variety of desires and feelings, and both quantitative and qualitative information from experts. The strength of this approach lies in its use of priorities based on ratio and proportion to capture the multiplicity of interactions and influences to make accurate predictions and furthermore, to make better decisions.

The parties considered according to their interests and influences fall in three groups: the U.S. and Israel, Palestinian and Arab countries (both friendly

and hostile), and U.S. allies (European and other) including the U.N. To save time and effort, we did not consider China, Russia, or India as sufficiently influential to include in our prioritization process.

Our analysis is carried out in three steps: (1) developing control criteria, and subcriteria for each of the BOCR, performing pairwise comparisons, and then prioritizing them, and (2) developing decision networks and synthesizing their priorities for each of the control criteria and then also for each of the BOCR and then (3) rating the best alternative for each of the benefits, opportunities, costs, and risks (BOCR) with respect to the strategic criteria: Middle East Peace, International Politics, and Human Well-being, to obtain priorities for the merits and using them to weight and combine the results to obtain the final outcome.

2. STRUCTURE OF THE DECISION PROBLEM

The entire ANP model consists of a three level decision-making network.

Merits

The top-level structure has the four BOCR merits and their control criteria represented in Figure 1.

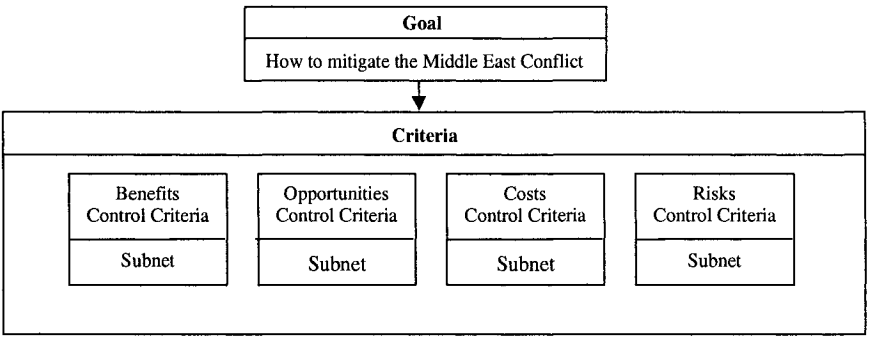

Figure 1. The ANP Main Top-level Structure

All subnets under each of the four BOCR merits are composed of three benefits criteria: economic, political, and social. Each of the subcriteria under the three components is described briefly below.

a. The Benefits Subnets

- Economic Benefits
  - Arms Control: Economic benefits driven by arms control
  - Economic Support from International Organizations: Economic support from the UN or IMF for peace settlement

  - Revitalization of Trade: Benefits from trade between Arab and Israel/US
- Political Benefits
  - Leadership: Building strong political leadership within each country
  - Support from Other Countries: Increasing political support from other countries for the effort to resolve the conflict
- Social Benefits
  - Improve Understanding between Islam and Christianity: Increase in possibility of understanding or sharing of religious value-differences between Islam and Christianity
  - Social Integration: Building consensus on the issue through the incorporation of diverse public opinions and interests

b. The Opportunities Subnets

- Economic Opportunities
  - Economic Development of the Middle East: Opportunity for economic development of the Middle East driven by conflict resolution
  - Revitalization of Oil Industry: Expansion and concentration of the oil industry
- Political Opportunities
  - Agreement on Establishing Palestinian State: Potentiality of agreement on establishing a Palestinian State
  - Protection of Allies: Opportunity to protect or maintain the allies
- Social Opportunities
  - Peace Settlement: Contribution to peace settlement in the Middle East
  - Possibility of Jewish Capital Investment: Opportunity to invest in the development of the Middle East through powerful Jewish capital

c. The Costs Subnets

- Economic Costs
  - Decrease in Defense Industry: potential cost driven by decrease in defense industry of the Israel/US and of Palestine/Arab
  - Resettlement Costs: Expenses for resettling or vacating Israeli occupancies
- Political Costs
  - Acknowledgement of Palestinian Rights: Political costs in achieving political mood change for acknowledgement of Palestinian Rights
  - Foreign Relations: Costs of rearrangement or persuasion for foreign relations
  - Peace Treaty: Costs for maintaining or substituting a peace treaty
- Social Costs

- Availability of Jewish Capital: Costs for availability of Jewish capital that have primarily been invested in western countries
- Public Support Costs: Costs for attaining consensus from the public

d. The Risks Subnets

- Economic Risks
  - Environmental Concerns: Risks of damaged environment that might be driven by the development or by the conflict
  - Opposition to flow of Jewish Capital: Risks of reluctance to flow of Jewish capital
- Political Risks
  - Split of Allies: Risks of split of allies
  - Terrorism: Risks of terrorism as an expression of opposition
- Social Risks
  - Religious Conflict: Risks of a religious conflict between Islam and Christianity
  - Split of Public Opinion: Possibility of split in public opinion on the issue

Networks Under the Control Criteria

There are in all 14 decision networks containing the alternatives of choice for each of the control criteria. Each control criterion has a network of actors and their influences in the third level. These decision networks show the relationship of each of the actors with respect to alternatives. Our analysis deals with two types of subnetworks. Two subnetworks, one for leadership and one for public support costs are shown in Figure 2.

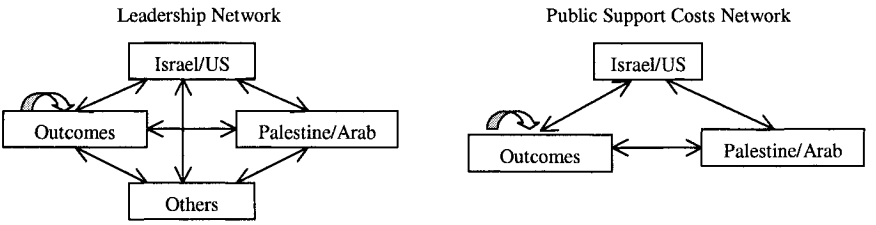

Figure 2. Decision Networks

We consider five potential outcomes to determine which has the greatest likelihood of long term success according to the projected ability of the parties to exert the influences needed to bring them about. Our analysis includes the following options or alternative outcomes:

- Interminable Confrontation: This is the ongoing confrontation and conflict as we know it today through military and other actions of bloodshed.

- Enforcement & Supervision of Settlement: This is to supervise negotiation between Israel and the Palestinians by international organizations, and enforce implementation of the agreements.
- Strict & Legal Settlement without Enforcement: This is to force both Israel and the Palestinians to observe their mutual agreement by legal means, by the UN, and by world public opinion.
- Good Faith Settlement as in the Rabin era: This is to maintain or establish a peace treaty designed to avoid military confrontations through carrying it out in a friendly way only between Israel and the Palestinians.
- Economic Assistance to the Palestinians: This is to help the Palestinians with economic development, education, and more generally planning a promising future.

Strategic Criteria and Their Priorities

Three strategic criteria along with subcriteria are developed to evaluate the priorities of the BOCR merits. They are: Middle East Peace, International Politics, and Human Well-Being.

- *Middle East Peace.* The Israeli-Palestinian conflict has largely affected the interests of several other countries including Arab, the U.S., and other countries. Resolution of the conflict is expected to eventually lead to peace in the Middle East. Acknowledgement of a Palestinian State can help permanent peace with social integration and graduate consensus on the issue. Also, security concern means that increasing one country's security can inevitably decrease the security of the other.

- *International Politics.* The Israeli-Palestinian conflict has been related to the international political sphere by affecting the foreign policy and military outlook of other countries not directly involved in the conflict, such as Russia and Saudi Arabia for diplomatic outlook, and Iraq, Iran, and North Korea for military outlook.

- *Human Well-being.* This is one of the aspirations to which resolving the conflict would contribute in no small measure. The conflict could lead to use of nuclear weapons by terrorists thus inviting retaliation against nations not directly responsible and eventually leading to a global conflagration. Human well-being is divided into capital investment, economic development, and religious concerns. Capital investment is driven by the economic effort to resolve the conflict and the hope that it would ultimately benefit all the people. Economic development also leads to rebuilding economies that have been stagnant due to the long lasting conflict. Religious concerns refer to tensions between East and West, and more significantly between Islam and Christianity that have taken place since the event of September 11, 2001.

Among the three strategic criteria to evaluate the BOCR merits, Middle East Peace has the highest priority (0.569) as opposed to International Politics of (0.129) and Human Well-Being of (0.301).

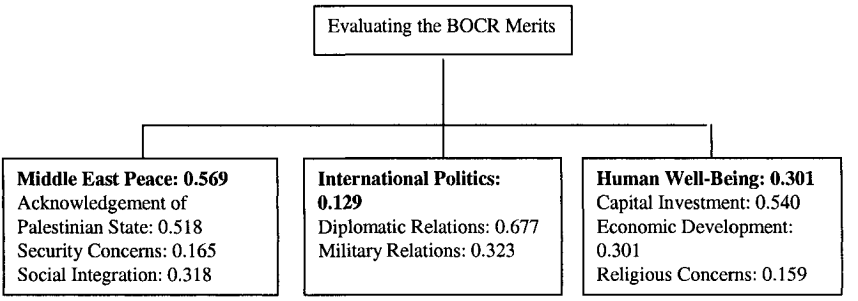

Figure 3. Hierarchy for Rating BOCR Merits

3. PRIORITIZATION

Priorities of the Control Criteria

The following table shows each of total 27 criteria prioritized by pairwise comparisons and its corresponding value in relation to other criterion through pairwise comparisons of the components. Among these 27 criteria, the criteria with the highlighted priorities are used to do the analysis because the sum of the priorities of these 14 criteria of them, which are Arms Control, Leadership, Social Integration, Agreement on Establishing Palestinian State, Security of Israel, Peace Settlement, Decrease in Defense Industry, Acknowledgement of Palestinian Rights, Foreign Relations, Availability of Jewish Capital, Public Support Costs, Split of Allies, Terrorism, and Split of Public Opinion accounts for 74.6% of the total. These criteria's priorities are above 0.030. We then renormalize 14 control criteria's priorities within their respective merits. Table 1 also shows normalized priorities for the 14 control criteria under each of BOCR merits.

In Table 2, among three benefits criteria, the economic benefits criterion has the highest priority of 0.444 as opposed to the social benefits criterion of 0.342 and the political benefits criterion of 0.215. Among benefits subcriteria, the highest priority given by arms control (0.289) reflects the opinion of some experts who think the conflict resolution will lead to the retrenchment of the expense in arms race because it eventually leads to arms control. The high priority given by social integration (0.249) reflects the diverse public opinions and interests can be incorporated and thus national consensus toward the conflict resolution can be built.

Among three opportunities criteria, the political opportunities criterion has the highest priority of 0.500 as opposed to the social opportunities criterion of 0.302 and the economic opportunities criterion of 0.197. Among opportunities subcriteria, the high priority given by security of Israel (0.267) reflects an

opportunity to achieve the security of Israel through the attempt of the conflict resolution. The high priority given by peace settlement (0.189) also reflects the hope of peace settlement in the Middle East.

Table 1. Control Criteria and Their Priorities

Merits	Criteria	Subcriteria	Local Priorities	Global Priorities	Normalized Priorities
Benefits	**Economic**	Arms Control	0.651	**0.289**	0.418
	0.444	Economic Support from Int'l Org.	0.137	0.061	-
		Revitalization of Trade	0.212	0.094	-
	Political	Leadership	0.716	**0.154**	0.222
	0.215	Support from Other Countries	0.284	0.061	-
	Social	Improve Understanding between Islam and Christianity	0.273	0.093	-
	0.342	Social Integration	0.727	**0.249**	0.360
Opportunities	**Economic**	Economic Development of Middle East	0.649	0.128	-
	0.197	Revitalization of Oil Industry	0.351	0.069	-
	Political	Agreement on Establishing Palestinian State	0.368	**0.184**	0.288
	0.500	Protection of Allies	0.098	0.049	-
		Security of Israel	0.534	**0.267**	0.417
	Social	Peace Settlement	0.625	**0.189**	0.295
	0.302	Possibility of Jewish Capital Investment	0.375	0.113	-
Costs	**Economic**	Decrease in Defense Industry	0.618	**0.105**	0.122
	0.170	Resettlement Costs	0.382	0.065	-
	Political	Acknowledgement of Palestinian Rights	0.557	**0.285**	0.332
	0.512	Foreign Relations	0.294	**0.151**	0.175
		Peace Treaty	0.149	0.076	-
	Social	Availability of Jewish Capital	0.319	**0.101**	0.118
	0.318	Public Support Costs	0.681	**0.217**	0.252
Risks	**Economic**	Environmental Concerns	0.314	0.053	-
	0.168	Opposition to flow of Jewish Capital	0.686	0.115	-
	Political	Split of Allies	0.371	**0.159**	0.256
	0.506	Terrorism	0.629	**0.347**	0.435
	Social	Religious Conflict	0.306	0.100	-
	0.326	Split of Public Opinion	0.694	**0.226**	0.309

Among three costs criteria, the political costs criterion has the highest priority of 0.512 as opposed to the economic costs criterion of 0.170 and the social costs criterion of 0.318. Among costs subcriteria, the highest priority given by acknowledgement of Palestinian rights (0.285) reflects the importance of political effort to acknowledge Palestinian rights in territories that Israel now occupies. Also, the high priority given by public support costs (0.217) means that actors involved in the conflict will need to put great effort to accomplish the support from the public with respect to policies for the conflict resolution.

Among three risks criteria, the political risks criterion has the highest priority of 0.506 as opposed to the economic risks criterion of 0.168 and the social risks criterion of 0.326. Among risks subcriteria, the highest priority given by terrorism (0.327) emphasizes the potentiality of terrorism as an expression of the complaint as to a specific policy to resolve the conflict. Similarly, the high priority given by split of public opinion (0.226) focuses on the difference of the preference of the public as to the implementation of a specific policy and thus the possibility of the split of public opinion.

Priorities of the BOCR Merits

The four BOCR merits are rated according to five intensities listed below along with their priorities. The rating outcome and final weights for each of the four merits are summarized in Table 3. These values are used as default values in an additive formula in developing an ANP model.

Table 3. Priority Ratings for the Merits: Benefits, Opportunities, Costs and Risks

	Middle East Peace (0.569)			International Politics (0.129)		Human Well-Being (0.301)			
	Acknowledgement of Palestinian State (0.518)	Security Concerns (0.165)	Social Integration (0.318)	Diplomatic Relations (0.677)	Military Relations (0.323	Capital Investment (0.540)	Economic Development (0.301)	Religious Concerns (0.159)	Priorities
Benefits	Very High	Low	High	High	Medium	High	High	Medium	**0.278**
Opportunities	High	Low	Medium	Low	Very Low	Medium	Medium	Low	**0.169**
Costs	Very High	High	High	Very High	Medium	Very High	High	Medium	**0.328**
Risks	High	High	Medium	High	Medium	High	Medium	Medium	**0.226**
Intensities:	Very High 0.42	High 0.26	Medium 0.16	Low 0.1	Very Low 0.06				

Synthesis of Each of the BOCR Merits

To obtain synthesized values under each of the BOCR merits for the alternatives, we multiply each of normalized priorities of 14 control criteria by the priority in ideal mode with respect to the alternatives and then add them up. We then divide each of the values by the sum to obtain synthesized priorities under each of the BOCR merits. Tables 4 through Table 7 show the overall synthesized priorities of each of the BOCR merits for the alternatives.

Table 4. Benefits' Overall Results

Alternatives	Arms Control (0.418)	Leadership (0.222)	Social Integration (0.360)	Final Outcome
Interminable Confrontation	0.235	0.251	0.212	0.2303
Economic Assistance to Palestinian	1	1	1	1.0000
Enforcement & Supervision of Settlement	0.717	0.752	0.707	0.7212
Good Faith Settlement	0.365	0.396	0.315	0.3539
Strict & Legal Settlement	0.498	0.527	0.455	0.4890

The alternative, Economic Assistance to the Palestinians, has high levels of benefits through effective arms control, building strong leadership, and achieving social integration, so that it becomes the best alternative when considering the three control criteria under benefits.

Table 5. Opportunities' Overall Results

Alternatives	Agreement on Establishing Palestinian State (0.288)	Security of Israel (0.417)	Peace Settlement (0.295)	Final Outcome
Interminable Confrontation	0.215	0.206	0.187	0.2030
Economic Assistance to the Palestinians	1	1	1	1.0000
Enforcement & Supervision of Settlement	0.298	0.701	0.67	0.5758
Good Faith Settlement	0.388	0.324	0.288	0.3318
Strict & Legal Settlement	0.194	0.463	0.433	0.3767

It is found that the opportunities of Economic Assistance to the Palestinians are so high through achieving agreement on establishing Palestinian State, security of Israel, and peace settlement in the Middle East that it becomes the best alternative as well when considering the three control criteria under opportunities.

Table 6. Costs' Overall Results

Alternatives	Decrease in Defense Industry (0.122)	Acknowledge-ment of Palestinian Rights (0.332)	Foreign Relations (0.175)	Availability of Jewish Capital (0.118)	Public Support Costs (0.253)	Final Outcome
Interminable Confrontation	1	1	1	1	1	1.0000
Economic Assistance to the Palestinians	0.23	0.283	0.241	0.243	0.251	0.2564
Enforcement & Supervision of Settlement	0.343	0.384	0.334	0.363	0.362	0.3622
Good Faith Settlement	0.738	0.744	0.703	0.714	0.751	0.7343
Strict & Legal Settlement	0.521	0.55	0.513	0.529	0.55	0.5375

We also found that economic assistance to the Palestinians has the lowest levels of costs through defense industry, acknowledgement of Palestinian rights, foreign relations, availability of Jewish capital, and achieving public support. Thus, it turns out to be the best alternative when the five control

criteria under costs are considered. It is closely followed by enforcement and supervision of settlement, and strict and legal settlement.

Table 7. Risks' Overall Results

Alternatives	Split of Allies (0.256)	Terrorism (0.435)	Split of Public Opinion (0.309)	Final Outcome
Interminable Confrontation	1	1	1	1.0000
Economic Assistance to the Palestinians	0.476	0.466	0.536	0.4902
Enforcement & Supervision of Settlement	0.549	0.577	0.63	0.5862
Good Faith Settlement	0.845	0.851	0.883	0.8594
Strict & Legal Settlement	0.643	0.705	0.73	0.6969

Similarly, economic assistance to the Palestinians appears to have the lowest level of risks through split of allies, possibility of terrorism, and split of public opinion, so that it becomes the best alternative when the three control criteria under risks are considered. It is also closely followed by enforcement and supervision of settlement, and strict and legal settlement.

4. Synthesis of All the BOCR Merits

The alternatives that have the highest priority under costs and risks are more costly or risky, and hence less preferred. To convert the priorities so that less preferred alternatives have lower values then more preferred ones, we invert the priority of each alternative and then normalize the inverted values. Table 8 gives the overall benefits, opportunities, costs, and risks results as well as the additive synthesis (bB+oO-cC-rR), which expresses the overall utility of the alternatives. We found that Economic Assistance to the Palestinians is the overall best alternative for all the actors to pursue. It has the highest benefits, the highest opportunities, the lowest costs as well as the lowest risks.

Table 8. Additive Synthesis

Alternatives	Benefits (0.278)	Opportunities (0.169)	Costs (0.328)	Risks (0.226)	Final Outcome
Interminable Confrontation	0.2303	0.2030	1.0000	1.0000	-0.4557
Economic Assistance to the Palestinians	1.0000	1.0000	0.2564	0.4902	0.2521
Enforcement & Supervision of Settlement	0.7212	0.5758	0.3622	0.5862	0.0465
Good Faith Settlement	0.3539	0.3318	0.7343	0.8594	-0.2806
Strict & Legal Settlement	0.4890	0.3767	0.5375	0.6969	-0.1342

5. SENSITIVITY ANALYSIS

a. Benefits and Opportunities

This study infers that the policy of the economic assistance to the Palestinians is the most beneficial to all actors. In order to make sure how stable the outcome of the analysis, sensitivity analysis is conducted. First, we increase and decrease one of the four BOCR merits, keeping the others proportionally the same. In Appendix, if benefits increase from its original priority 0.278 to 0.5, and the sum of the other three merits composes the rest of 0.5, the economic assistance outcome is still preserved as the best policy among the five alternatives. Thus, as the priority of benefits increases, the best policy turns out to be the economic assistance policy. Enforcement & supervision of settlement outcome keeps becoming the second best policy as the benefits priority increases. Additionally, interminable confrontation still becomes the least desirable policy.

Similarly, if opportunities increase from its original priority 0.169 to 0.5, the economic assistance policy is preserved as the best policy as well. Also, enforcement & supervision of settlement still turns out to be the second best policy and interminable confrontation is expected to be the least recommendable policy. Consequently, we find that no matter how much we increase or decrease the priorities of benefits and opportunities, the overall rank of the final outcome is preserved although these experiments change the magnitudes of the superiority of the best alternative.

b. Costs and Risks

Additionally, if costs priority increases from its original priority 0.328 to 0.5, the economic assistance policy still turns out to be the best policy to deal with. It is found that the overall rank of the five alternatives is preserved

although the magnitudes of the priorities slightly change. Similarly, as the priority of risks increases from its original priority 0.226 to 0.5, the economic assistance policy is still preserved as the best policy although its superiority decreases gradually. However, we find that the overall rank of the five alternatives never change although the magnitudes of the priorities change to some extent.

6. CONCLUSIONS

The final outcome suggests that the best policy to mitigate the Middle East Conflict is to provide the Palestinians with economic assistance. As of now, this policy has never been considered to be essential in resolving the conflict by any of the actors. It turns out to be critical in our analysis of the negotiations but not how to implement it in practice. We believe that traditional negotiations have not moved to the conflict closer to resolution because of lack of a strong recognition of the need to give the Palestinians compensation for at least lots of their properties and perhaps make sure that matters have been evenly balanced as far as they feel their rights are concerned. Furthermore, this kind of resolution does not focus as much on land, territory, and military action as much as it does on humane values and long term future relations.

The need for a peace settlement is as strong as ever. Admitting that the Palestinians are fighting for freedom and independence, economic assistance must be provided in a way that ultimately ensures Palestinian self-sufficiency and sustainability. This alternative has to be based on a great deal of collaboration among Israel, the Palestinians, the U.S., Arab and other countries. Assistance must be provided both for economic development and for education to help the Palestinians move into the future.

Four years after this study, in the August 4, 2005 issue of the Economist Newspaper there appeared and article about "The Compassionate Capitalist", that essentially indicates there is an effort to implement precisely the best alternative of this chapter:

"Sir Ronald Cohen is now expected to devote his energy to two causes long close to his heart. One is the Middle East peace process. He was among the Jews thrown out of Egypt in the 1950s. He is chairman of the Portland Trust, which, among other things, is promoting (not without controversy) economic development in Palestine. Sir Ronald believes that economic growth for the Palestinians is crucial if there is to be lasting peace with Israel."

It was reported in the December 28, 2005 issue of the Wall Street Journal that James Wolfensohn, former head of the World Bank, now special envoy to the Quartet whose members are the U.S., the European Union, Russia and the United Nations, in the Israeli-Palestinian region, is working towards resolving the conflict there through both political compromise and economic development. He has contacted world leaders and began discussions over what could eventually become $9 billion in financial aid and investment for the Palestinians.

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CHAPTER 11

THE CONFLICT BETWEEN CHINA AND TAIWAN

Wen-Lin Kung, Min-Hung Lu and Hsiao-Chi Liu
(Spring 2005)

1. INTRODUCTION

A long-festering problem now threatens the peace and stability of the Asia-Pacific region. As Assistant Secretary of State for East Asian and Pacific Affairs Stanley Roth warned Congress on March 25, 1999, the Taiwan issue—or, as we prefer to say, the "Divided China" problem—has become "one of the United States most complex and important foreign policy challenges for many years to come." Most of countries are concerned that the crisis has arrived.

The origins of today's divided China problem go back some sixty years ago to a very different time and place. At that time, two political parties, the Kuomintang (KMT) and the Communist Party of China (CPC), and their armies fought each other while both tried to win over the Chinese people to their ideals. As the Chinese civil war seemed to be ending in early 1950, one of those unusual historic turning points took place: The U.S. government intervened in the Chinese civil war by allying with the ROC (Republic of China) to counter the PRC (People's Republic of China). In so doing, the "divided China" situation turned out to be a source of instability in Asia.

2. POSSIBLE ALTERNATIVES

Since the two parties introduced different ideals, Democracy (Taiwan) and Communism (mainland China), into the government system, there were two Chinese regimes opposing each other across the Taiwan Strait. The possible options for them to end the long lasting Chinese civil war and resolve the divided China problem are:

- *Peaceful unification*
- *Stay as in the present*
- *Independence of Taiwan*
- *China armed takeover of Taiwan*

The goal is to develop a Superdecisions ANP model to determine what Taiwan and China should do to resolve the separated China situation. The benefits, opportunities, costs, and risks (BOCR) networks are created and each has a subnet. The benefits network indicates the alternative that yields the most benefit and the opportunities network indicates the alternative that offers the most opportunities. The costs and risks networks indicate the alternative that is the most costly or poses the greatest risk to the Taiwan – China decision.

3. BOCR MODEL

Strategic Criteria

In pursuit of this decision, we consider five strategic control criteria: *"China Government"*, *"International Political Power"*, *"Taiwan Economy Power"*, *"Taiwan Government"*, and *"Taiwanese"*. These five strategic control criteria influence the weight of the BOCR. They were used to implement a rating system in the ANP program in order to prioritize the BOCR (see Figure 1).

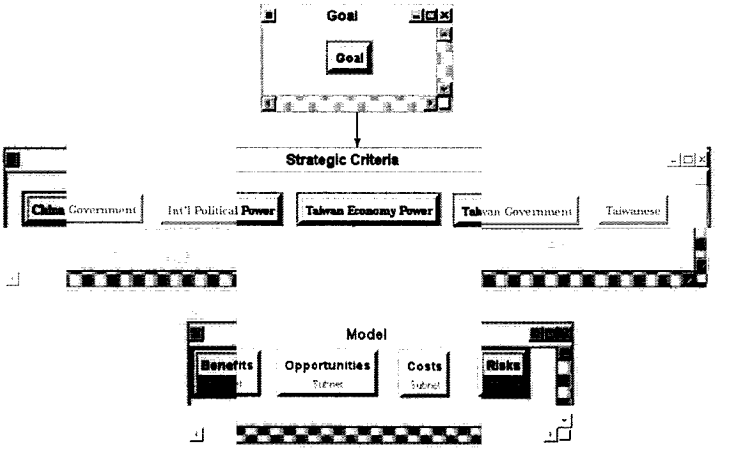


Figure 1. BOCR Model and Strategic Criteria

Control Criteria

Under the benefits, opportunities, costs, and risks models, different clusters define the interactions with respect to the control criteria. Each subnet under the BOCR has the same control criteria. They are Political, Social, and Economic (see Figure 2). The same control criteria were considered for all BOCR networks.

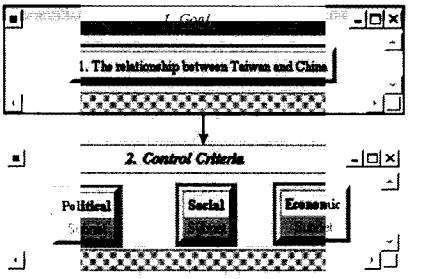


Figure 2. Control Criteria

BENEFITS

Subnet under Political

1. *Stability of international relations cluster* – This cluster represents the serious concern of other countries about the four alternatives. Especially Japan and the United States, have closest relationship with divided China. It includes: *"US Pacific Defense System"* and *"Japan's concern about National Security"*.
2. *Security cluster* – This cluster defines how Taiwan would defend its territory in terms of four alternatives, involving two powers: *"US Army's Support"* and *"National Defense, ROC"*.
3. *China cluster* – This cluster shows that three influences from mainland China could interact with the four alternatives. It includes: *"China Political Influence"*, *"China Attacks"*, and *"Vision of One China"*.
4. *Taiwan's Vision cluster* – This cluster represents two main voices from inside Taiwan, *"One Side, One Country"* and *"We are a Family"*.
5. *National System cluster* – This cluster indicates the difference between two ideals in the struggle across the Taiwan Strait. It includes: *"Democracy"* and *"Communism"* (see Figure 3).

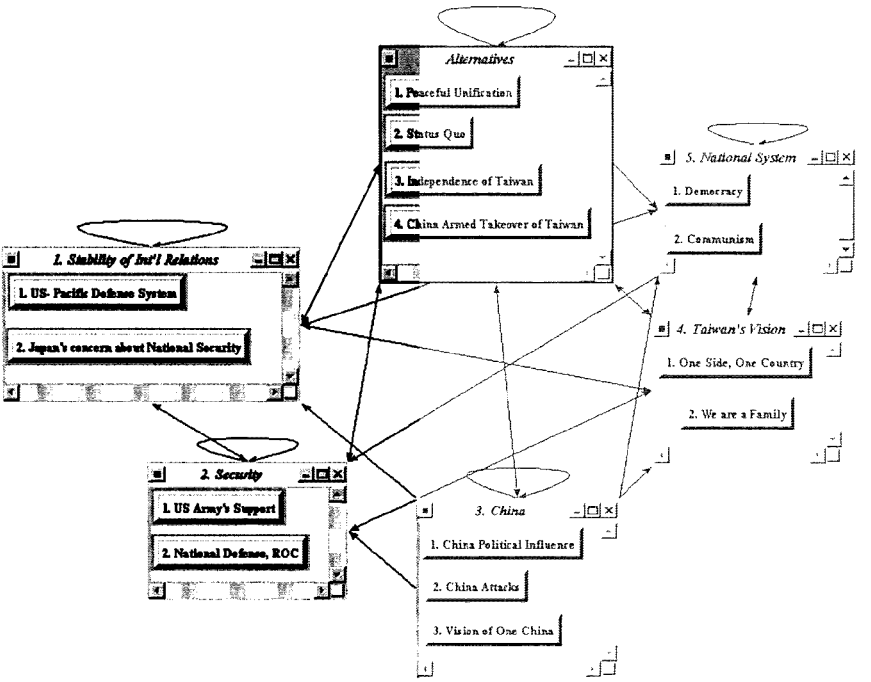


Figure 3. Subnet under Political Benefits

Subnet under Social

1. *Social System cluster* – This cluster represents the different social structures started and developed by the opposing ideals, *"Democracy"* and *"Communism"*.

2. *Culture Difference cluster* – This cluster represents the different *"Standard of Living"* and the different point of view of *"Human Rights"* as issues evaluated in terms of the four alternatives (see Figure 4).

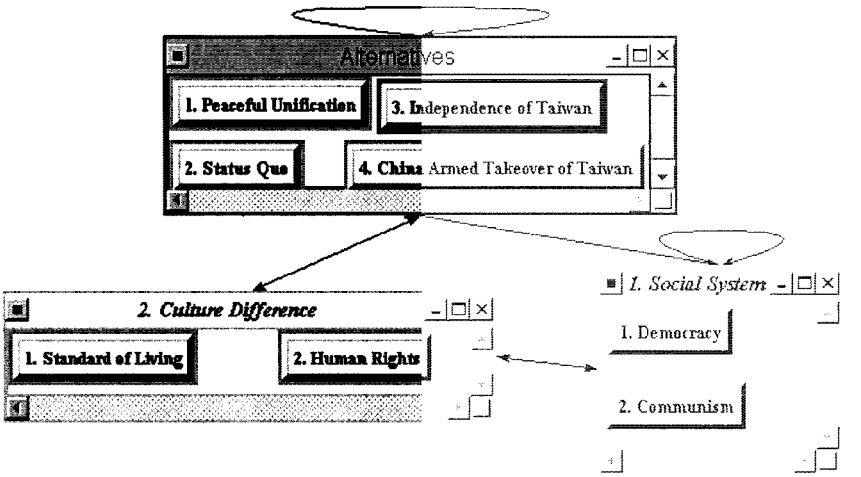


Figure 4. Subnet under Social Benefits

Subnet under Economic

1. *Business cluster* - This cluster represents the factors of running businesses that could be influenced differently in terms of the four alternatives. It includes: *"Transportation Cost"*, *"Labor Cost"*, *"Market Entry Barriers"*, *"Labor Quality"*, and *"Management Expertise"*.

2. *Individual cluster* – This cluster identifies the new situation that an individual might need to face, in terms of the four alternatives. It includes: *"Fierce Job Competition"* and *"Price Level"* (see Figure 5).

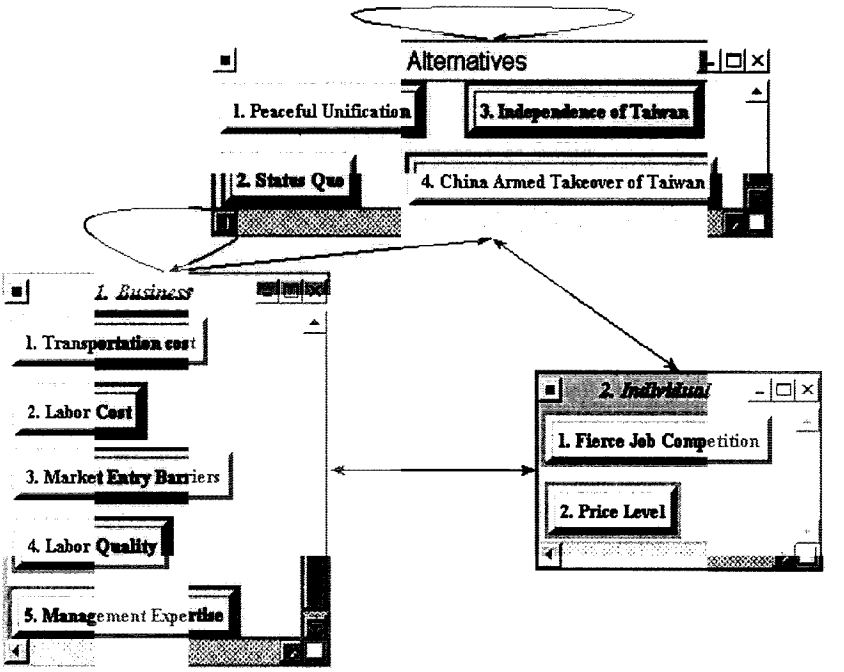


Figure 5. Subnet under Economic Benefits

OPPORTUNITIES

Subnet under Political

1. *International Relations cluster* - This cluster represents the opportunities afforded for international relations in terms of the four alternatives. It includes: *"Increase Political Power"*, and *"International Recognition"* (see Figure 6).

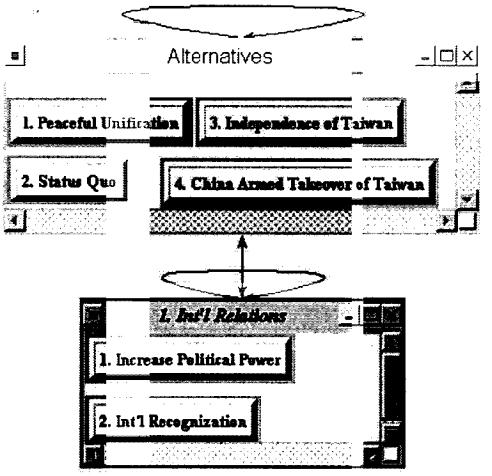


Figure 6. Subnet under Political Opportunities

Subnet under Social

1. *Social Issue cluster* - This cluster represents the opportunities related to social issues in China and Taiwan in terms of the four alternatives. It includes: *"More Education Resources"*, *"Improve Quality of Life in China"*, *"Improve Human Rights in China"*, and *"Higher Social Status"* (see Figure 7).

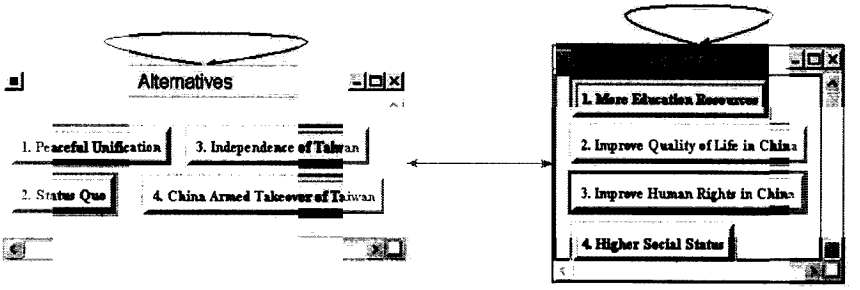


Figure 7. Subnet under Social Opportunities

Subnet under Economic

1. *Taiwan cluster* – This cluster identifies the opportunities to Taiwan in terms of the four alternatives. It includes: *"Greater Market Openness"*, *"Access to Natural Resources"*, *"More Job Opportunities for Taiwanese"*, and *"Increase Taiwan's Economic Power"*.

2. *China cluster* – This cluster identifies the opportunities to China in terms of the four alternatives. It includes: *"More Job Opportunities for the Chinese People"*, and *"More Investment Opportunities in Taiwan"* (see Figure 8)

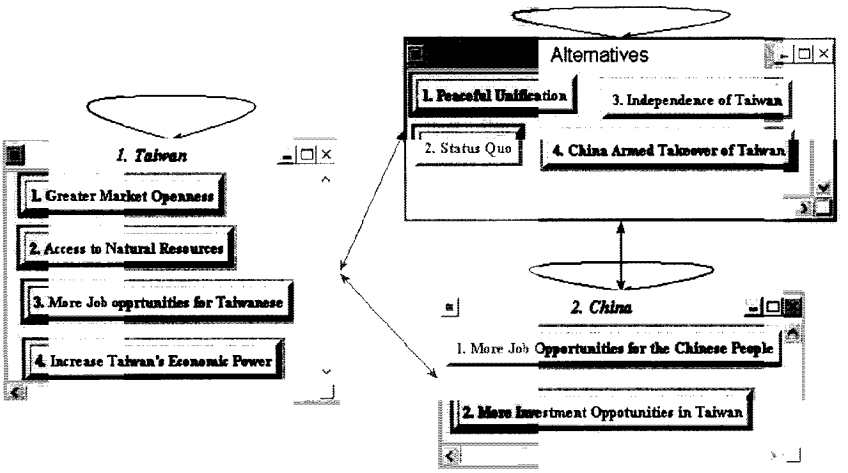


Figure 8. Subnet under Economic Opportunities

COSTS

Subnet under Political

1. *Taiwan to International cluster* – This cluster represent the costs that Taiwan needs to incur to get international support in terms of the four alternatives. It includes: *"Lobby costs"* and *"International support"*.

2. *Taiwan cluster*– This cluster identifies the costs to Taiwan domestically in terms of the four alternatives. It includes: *"Autonomy"*, *"High National Defense Budget"*, and *"Voter Support"*.

3. *China cluster* – This cluster identifies the costs to China in terms of the four alternatives. It includes: *"Tangible Costs to get Taiwan back"* and *"Intangible Costs to get Taiwan back"* (see Figure 9).

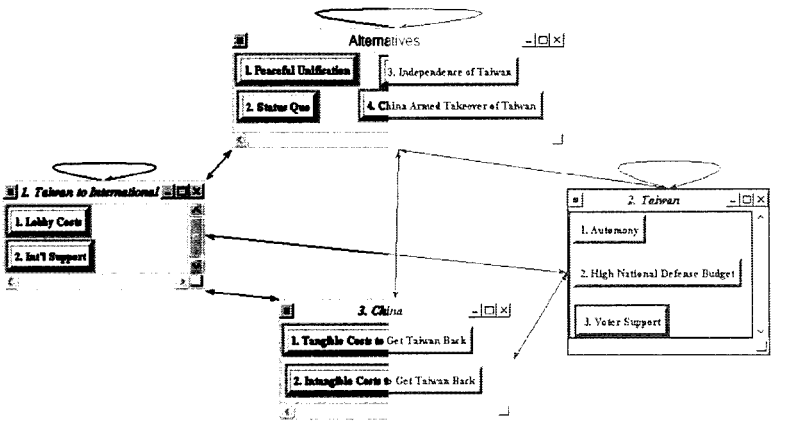


Figure 9. Subnet under Political Costs

Subnet under Social

1. *China cluster* – This cluster identifies the cost to China in terms of the four alternatives. It includes: *"Tangible Costs to get Taiwan back"* and *"Intangible Costs to get Taiwan back"*.

2. *"Blue" Taiwanese cluster* – This cluster identifies the cost to Taiwan in terms of the four alternatives. It includes: *"Fears"*, *"Uncertain Society"*, *"Casualties"* and *"People Movement"* (see Figure 10).

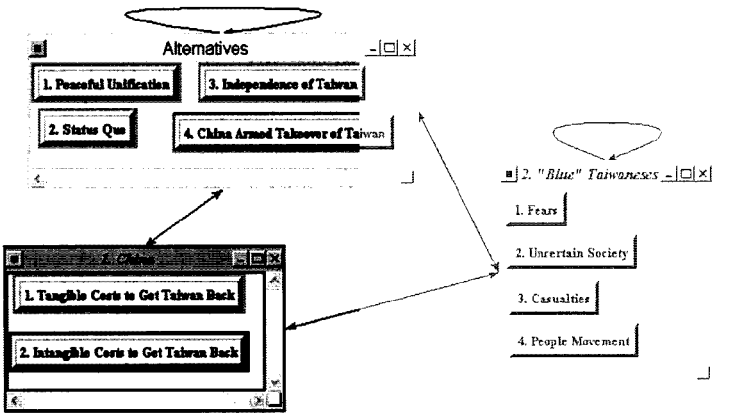


Figure 10. Subnet under Social Costs

Subnet under Economic

1. *International cluster* – This cluster identifies the costs that both China and Taiwan would have to incur in the international arena in terms of the four alternatives. It includes: *"Hobbling Global Economy"*, *"Capital Fleeing"* and *"Losing Investors' confidence"*.

2. *Taiwan cluster* – This cluster identifies the cost to Taiwan domestically in terms of the four alternatives. It includes: *"Currency Depreciation", "Damage to Domestic Economy"* and *"Price Fluctuation".*

3. *China cluster* – This cluster identifies the cost to China in terms of the four alternatives. It includes: *"Tangible costs to get Taiwan back" and "Intangible Costs to get Taiwan back".*

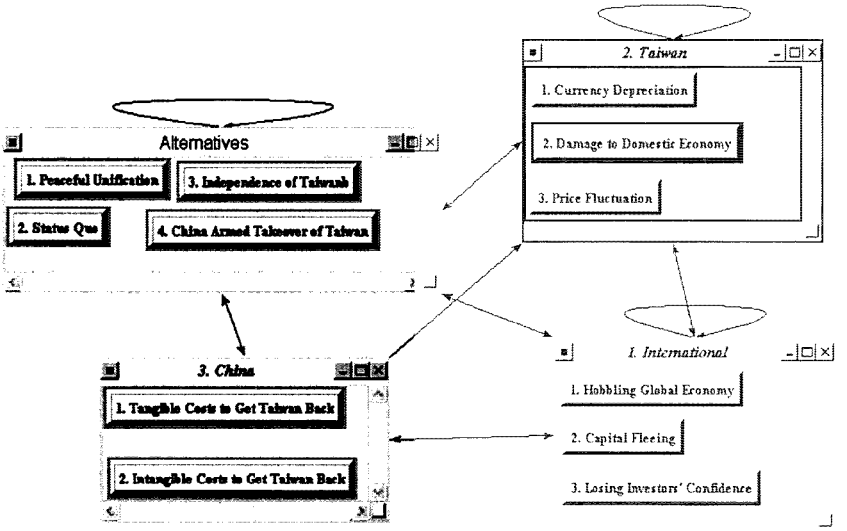


Figure 11. Subnet under Economic Costs

RISKS

Subnet under Political

1. *International cluster* –This cluster represents the risks to global and international relations in terms of the four alternatives. It includes: "*Alliance between US & China*", "*China's growing power*", and "*Stability of Asia-Pacific.*"

2. *Taiwan cluster* –This cluster identifies the risks to the Taiwanese and to the Taiwan Government in terms of the four alternatives. It includes: "*Threat of China attack*", "*The Government's decision*", and "*Budget crow-out effect.*"

3. *China cluster* – This cluster represents what risks to China in terms of the four alternatives. China has been saying it will prohibit Taiwan from independence from China regardless of all risks. Again this cluster simply includes "*Tangible Risks to China*" and "*Intangible Risks to China*" (see Figure 12).

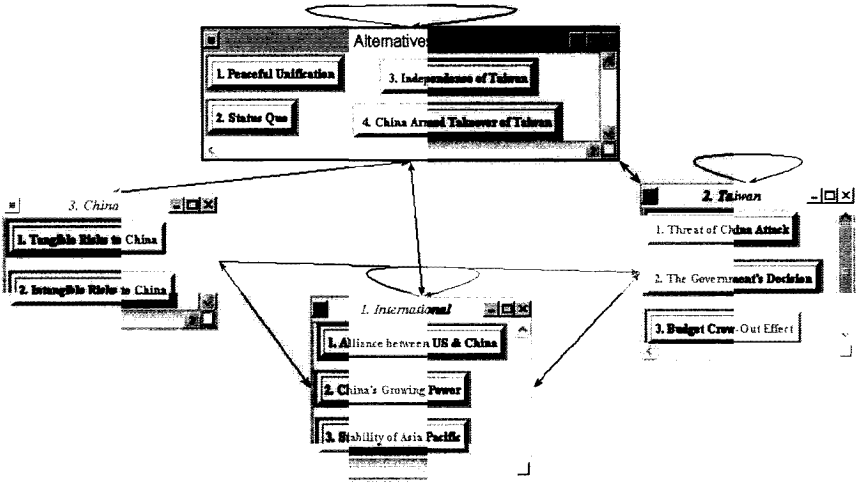


Figure 12. Subnet under Political Risks

Subnet under Social

1. *Social Risks cluster* – This cluster stands for the risks to both China's and Taiwan's societies with regard to the four alternatives. It includes: (1) *Birth rate,* (2) *Crime rate,* (3) *Irreconcilable,* (4) *Refugees issues, and* (5) *Ideology* (see Figure 13).

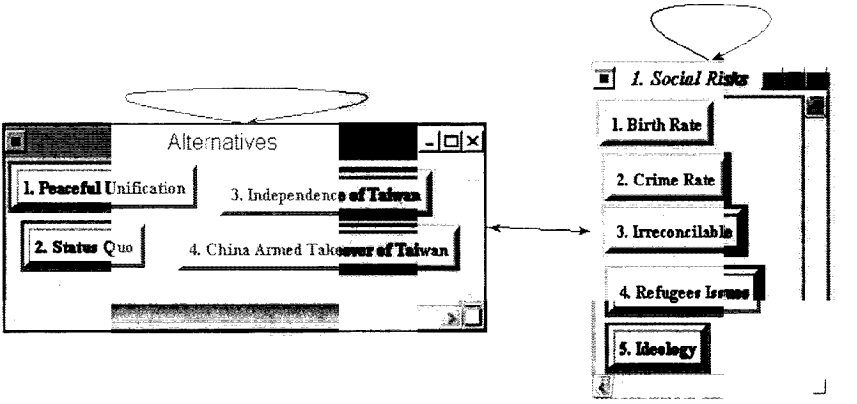


Figure 13. Subnet under Social Risks

Subnet under Economic

1. *International cluster* – This cluster represents the economic risks the global market would take in terms of the four alternatives. The risks include "*Damage international logistic network*", "*Trade sanctions against China*", and "*Damage the global supply chain.*"

2. *Domestic cluster* – This cluster identifies the risks to Taiwan's domestic economy and market. It includes the risks of "*GDP slips*", "*Exhausted resources in Taiwan*", and "*Economic isolation*" (see Figure 14).

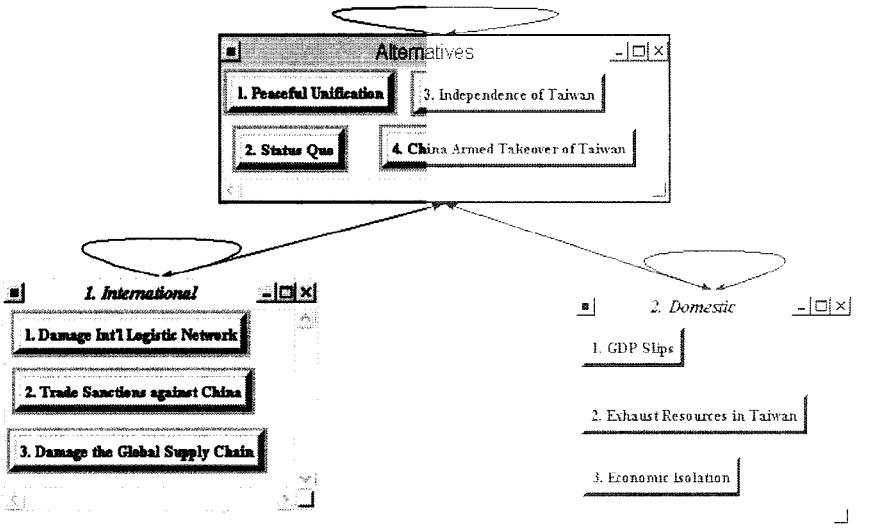


Figure 14. Subnet under Economic Risks

4. OVERALL SYNTHESIZED RESULTS

Each of the subnets under the control criteria for the benefits, opportunities, costs and risks yields priorities for the alternatives. These priorities in ideal form are synthesized to obtain the overall priorities of the alternatives with respect to the benefits, opportunities, costs and risks (Table 1).

Table 1. Alternatives Priorities wrt the Control Criteria and Synthesis

BENEFITS	Political	Social	Economic	
Alternatives	0.6250	0.1365	0.2385	Synthesis
1. Peaceful Unification	1.0000	0.7285	1.0000	0.9629
2. Status Quo	0.7723	1.0000	0.7436	0.7965
3. Independence of Taiwan	0.5992	0.5245	0.4864	0.5621
4. China Armed Takeover of Taiwan	0.6484	0.5245	0.7039	0.6447

OPPORTUNITIES	Political	Social	Economic	
Alternatives	0.6250	0.1365	0.2385	Synthesis
1. Peaceful Unification	0.9915	0.8353	1.0000	0.9722
2. Status Quo	1.0000	1.0000	0.8333	0.9602
3. Independence of Taiwan	0.7155	0.9039	0.6401	0.7232
4. China Armed Takeover of Taiwan	0.6019	0.7232	0.7767	0.6601

COSTS	Political	Social	Economic	
Alternatives	0.6250	0.1365	0.2385	Synthesis
1. Peaceful Unification	0.4988	0.4029	0.3921	0.4603
2. Status Quo	0.6861	0.4729	0.4117	0.5915
3. Independence of Taiwan	0.9843	0.8385	0.8140	0.9238
4. China Armed Takeover of Taiwan	1.0000	1.0000	1.0000	1.0000

RISKS	Political	Social	Economic	
Alternatives	0.6250	0.1365	0.2385	Synthesis
1. Peaceful Unification	0.4199	0.6187	0.4411	0.4521
2. Status Quo	0.4477	0.5804	0.4213	0.4595
3. Independence of Taiwan	0.8611	0.9312	0.7284	0.8390
4. China Armed Takeover of Taiwan	1.0000	1.0000	1.0000	1.0000

To synthesize the results, first the benefits, opportunities, costs and risks are rated according to the strategic criteria using the best ranked alternative as the norm under each of the merits. Table 2 gives the normalized priorities of the benefits, opportunities, costs and risks.

Table 2. BOCR Ratings and Intensity Scale

	China Government 0.292707	Int'l Political Power 0.203558	Taiwan Economy Power 0.098507	Taiwan Government 0.212643	Taiwanese 0.192585	Normalized Priorities
Benefits	Medium	Very Strong	Very Strong	Medium	Very Strong	**0.2821**
Opportunities	Medium	Weak	Very Strong	Medium	Very Strong	**0.2075**
Costs	Strong	Medium	Very Strong	Strong	Medium	**0.2202**
Risks	Weak	Strong	Very Strong	Very Strong	Very Strong	**0.2902**

Intensities:	Very Strong	Strong	Medium	Weak
	1.0000	0.5684	0.3026	0.1595

The priorities of the alternatives are obtained by combining the results from the benefits, opportunities, costs and risks models using a multiplicative (BO/CR) and an additive negative (bB+oO-cC-rR) composition principle (see Table 3).

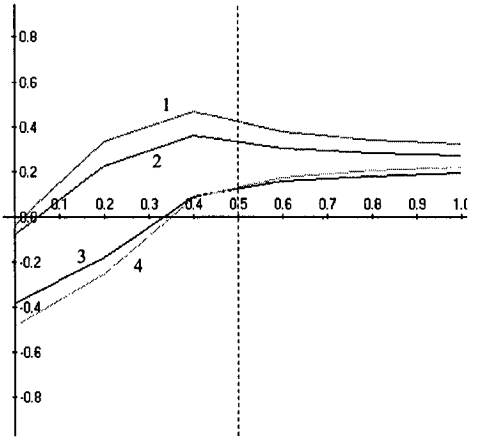
Table 3. Multiplicative and Additive Syntheses of BOCR Results

	Benefits	Opportunities	Costs	Risks	MULTIPLICATIVE	ADDITIVE
Alternatives	0.2821	0.2075	0.2202	0.2902	BO/CR	bB+oO-cC-rR
1. Peaceful Unification	0.9629	0.9722	0.4603	0.4521	**4.4988**	**0.2408**
2. Status Quo	0.7965	0.9602	0.5915	0.4595	2.8140	0.1604
3. Independence of Taiwan	0.5621	0.7233	0.9238	0.8390	0.5246	-0.1382
4. China Armed Takeover of Taiwan	0.6447	0.6601	1.0000	1.0000	0.4256	-0.1915

The results indicate that **Peaceful Unification** is the best scenario for the future relationship of China and Taiwan.

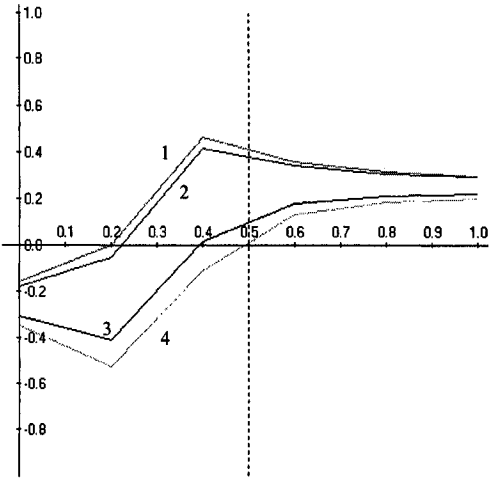
5. SENSITIVITY ANALYSIS

The following graphs show sensitivity analysis of the 4 alternatives for the relationship between China and Taiwan.



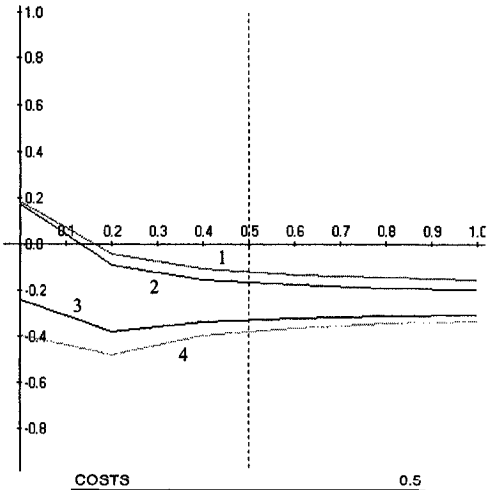
BENEFITS	0.5
Alternatives	
1. Peaceful Unification	0.421
2. Status Quo	0.331
3. Independence of Taiwan	0.122
4. China Armed Takeover of Taiwan	0.125

Figure 15. Sensitivity analysis under benefits



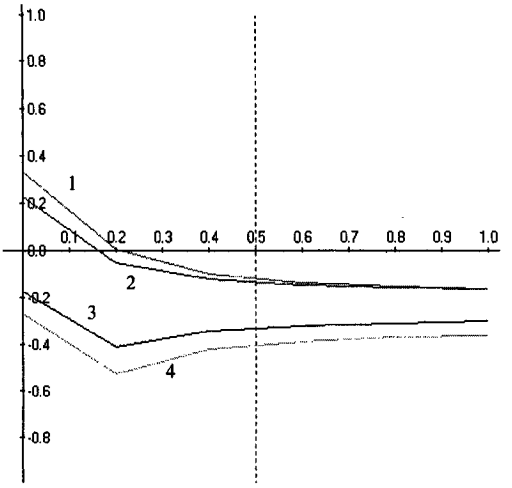
OPPORTUNITIES	0.5
Alternatives	
1. Peaceful Unification	0.407
2. Status Quo	0.376
3. Independence of Taiwan	0.095
4. China Armed Takeover of Taiwan	0.009

Figure 16. Sensitivity analysis under opportunities



COSTS	0.5
Alternatives	
1. Peaceful Unification	-0.122
2. Status Quo	-0.166
3. Independence of Taiwan	-0.332
4. China Armed Takeover of Taiwan	-0.379

Figure 17. Sensitivity analysis under costs



RISKS	0.5
Alternatives	
1. Peaceful Unification	-0.12
2. Status Quo	-0.138
3. Independence of Taiwan	-0.334
4. China Armed Takeover of Taiwan	-0.408

Figure 18. Sensitivity analysis under risks

6. CONCLUSIONS

1. *No one wants to fight*

Based on the synthesized results, one clearly sees that *Peaceful Unification* is the ideal scenario among all the alternatives followed by the *Status Quo* alternative. The other two alternatives (*Independence of Taiwan* and *China Armed Takeover of Taiwan*) are far behind in the overall result. This provides the favorable conclusion that war is never a desired option for China and Taiwan.

2. *Status Quo will NOT be a permanent situation*

Before developing the model, it was thought that *Status Quo* would be the best option because it was basically more favorable to Taiwan and overall perhaps also to China. However, by doing this model, it was realized that *Status Quo*, in the long run, would keep Taiwan under great pressure from China's threats and thus would hurt Taiwan's society and economy. That is why *Status Quo* does not come out to be the ideal solution.

3. *Go Independent = War + Loss*

Undoubtedly, by becoming independent Taiwan would be a shame for China. China has been announcing publicly that, once Taiwan goes independent, it would launch a war to take it over at any cost. According to the

sensitivity analysis under benefits, the *China Armed Takeover of Taiwan* would surpass the *Independence of Taiwan* alternative as more weight is assigned to benefits. This is understandable because, as Taiwan becomes independent, it would lose international support since not many countries support its independence. Moreover, Taiwan would lose economic advantage because China would block Taiwan's business and trade. The foregoing shows that the independence option would bring more costs than benefits, and more risks than opportunities.

It is thought that this model is both realistic and reliable in portraying the current situation between China and Taiwan. The authors are very confident about the outcome and conclusions as they mirror many studies made about the subject. While the criteria and priorities may change with the passage of time the ideal solution is likely to remain for reasons given above.

CHAPTER 12

U. S. RESPONSE TO NORTH KOREAN NUCLEAR THREAT

Jeff Freund, Hang-Jun Kang and Sang Soo Lee
(Spring 2005)

1. INTRODUCTION

As more and more countries around the world begin to develop nuclear weapons, the threat of a nuclear attack against the United States increases. In addition to the threat directly posed by these countries, there is also the threat that nuclear weapons could be sold or given to other hostile countries or to terrorists. North Korea is one country whose development of nuclear weapons represents a threat to the United States, somewhat aggravated by the confrontational attitude of its leader, Kim Jung Il.

The purpose here is to determine what best action the United States can take in response to the potential nuclear threat from North Korea.

The current United States policy is to only deal with North Korea through six-nation talks involving the United States, North Korea, China, Russia, Japan, and South Korea. Some economic sanctions are in place. The United States has not ruled out using incentives, but would not talk about them unless North Korea first agrees to abandon its nuclear program.

2. ALTERNATIVE COURSES OF ACTION

1. **Attack on Facilities**: This alternative involves an attack whose purpose would be to take out North Korea's nuclear facilities.

   Advantages: Using this alternative has the advantage of not having to deal with Kim Jung Il. Since he has not been very responsive to talks up to this point, there may be no way to achieve a satisfactory solution by dealing with him. In addition, this alternative would involve using less troops and resources than a full scale attack.

   Disadvantages: Hostile response from North Korea and other countries, damage to U.S. reputation, and the chance that some facilities may be missed and the threat would remain with the certainty of escalating the conflict.

2. **Full Scale Attack**: This alternative involves a full scale attack on the North Korean soil.

Advantages: A full scale attack could ensure that North Korea's weapon facilities are destroyed. Also, it would send a sobering message to other countries that are possibly developing nuclear weapons such as Iran.

Disadvantages: Given the large presence of U.S. troops in other countries, such as Iraq, Afghanistan and the Balkans, it might be difficult to gather enough forces for a full scale assault without adequate preparation for a major war. Such a war would undoubtedly create major diplomatic problems with East Asian countries and could damage U.S. credibility in the region. It could also affect the political stability of the region.

3. **Economic Sanctions**: This involves using economic sanctions to punish North Korea until it agrees to give up its nuclear program.

   Advantages: This strategy has not had any negative results so far. It is not as costly as some of the other alternatives.

   Disadvantages: Economic sanctions have failed to eliminate the threat of North Korea's nuclear weapons. Its leadership does not seem to care about the people's well-being.

4. **Remove Sanctions, No Other Action**: This involves removing all sanctions and not pursuing any other course of action such as using incentives or attacking North Korea.

   Advantages: Removing sanctions could make the U.S. appear to be fair in the eyes of some hostile countries. There are minimal direct economic costs to this alternative.

   Disadvantages: The U.S. might seem weak in the eyes of some enemy countries, and upset allies that continue to use sanctions. In addition, if North Korea's borders were more open to trade, this could make it easier for nuclear weapons to leave the country and get into the hands of terrorists or enemy countries.

5. **Negotiate with Incentives**: This involves negotiating by tempting North Korea with positive offers that can serve as incentives.

   Advantages: The use of incentives could make the U.S. appear fair to other countries. North Korea might be more responsive to this approach than to less friendly alternatives.

   Disadvantages: This could make the U.S. appear weak. Providing incentives would only encourage other countries to act as North Korea has acted. Incentives have a direct economic cost.

6. **Combination**: This involves negotiating with North Korea by using both sanctions and incentives as bargaining tools (the carrot and the stick approach).

   Advantages: In addition to making the U.S. appear fair while not looking as weak as with some of the alternatives, it would also provide North Korea with the most reasons to agree to U.S. demands.

   Disadvantages: Incentives have costs and may encourage other countries to act like North Korea.

7. **Take out Kim Jung Il**: This involves eliminating/deposing the leader of North Korea, Kim Jung Il as with Saddam Hussein.

   Advantages: Removing Kim Jung Il may result in a new leader who is more responsive to U.S. demands. This would show other enemy countries that the U.S. is serious in dealing with dictators.

   Disadvantages: There is a strong possibility that this would lead to an attack from North Korea and create further hostility from enemy countries and terrorists. It could also damage the U.S. image in the eyes of ally countries.

3. BENEFITS, OPPORTUNITIES, COSTS AND RISKS

The alternative courses of action model need to be evaluated according to their merits based on benefits, opportunities, costs and risks (BOCR). The merits in turn are evaluated in terms of the strategic criteria depicted in Figure 1. Before the BOCR model is evaluated with respect to the strategic criteria we need to identify the best alternative course of action in each of the merit categories.

Benefits Subnet:

The benefits subnet consisted of three criteria (see Figure 2). Each of these criteria also had subcriteria. To determine which subcriteria were important enough to have their own subnets, subcriteria were selected when they accounted for at least 75% of the importance of the benefits subnet. These relative priorities were found by multiplying the priority of each criterion by the priority of each subcriterion within the corresponding subcriteria cluster. For example, among the criteria, National Security had a priority of 0.637, Economic had a priority of 0.105, and Political had a priority of 0.258. In the National Security Subcriterion cluster, Eliminate Potential Nuclear Threat had a priority of 0.8, and Anti-Terrorism had a priority of 0.2.

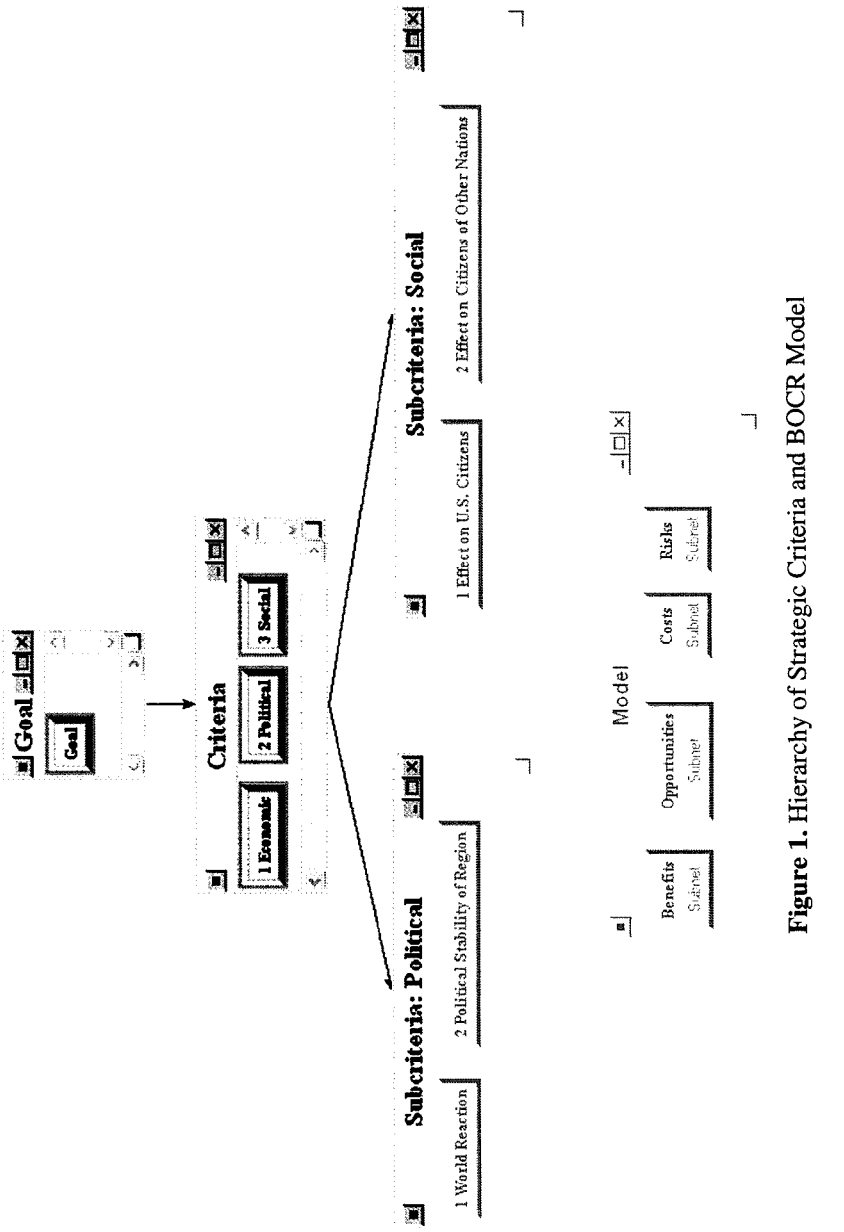


Figure 1. Hierarchy of Strategic Criteria and BOCR Model

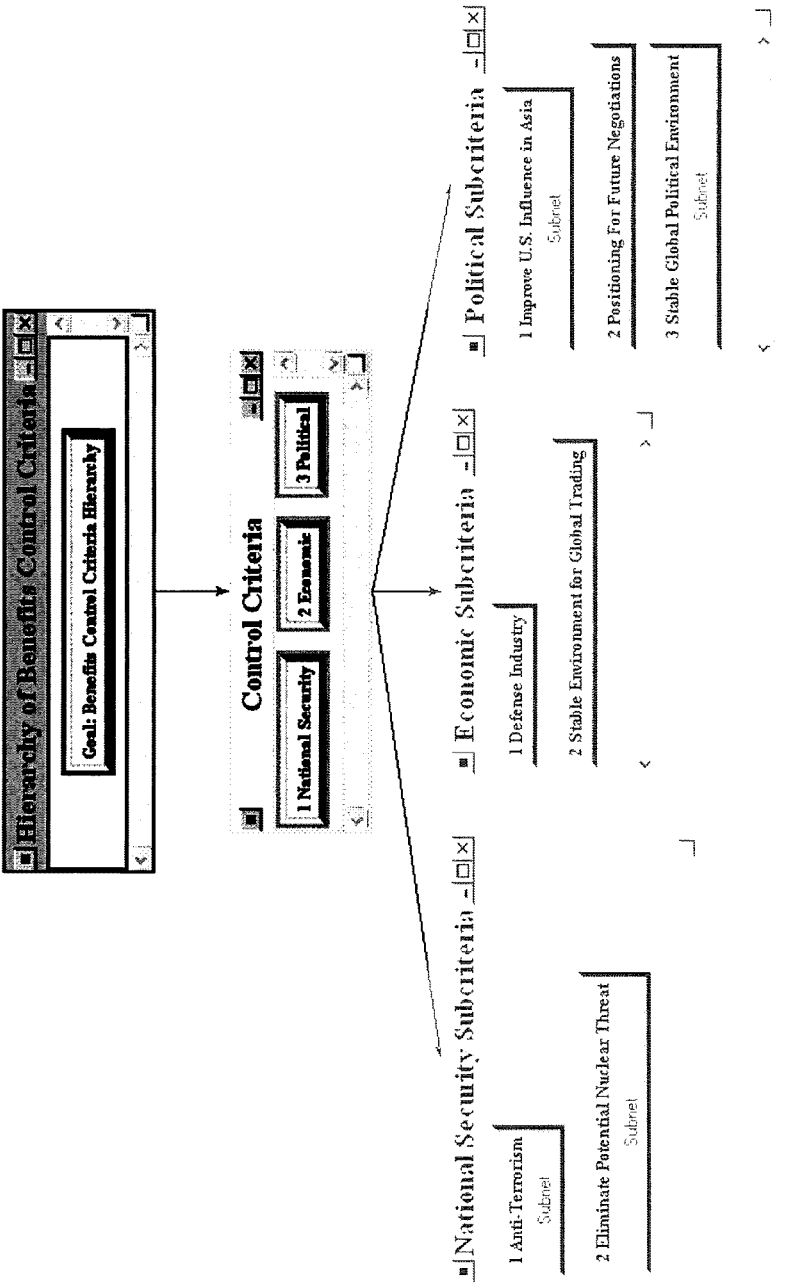


Figure 2. Hierarchy of Benefits Control Criteria

Therefore, the relative priority of Eliminate Potential Nuclear Threat was 0.637x0.8 = 0.51. This method for determining which criteria and subcriteria require subnets was used for the costs and risks subnets as well. Table 1 shows all the criteria and subcriteria along with their relative priorities. The subcriteria that have subnets are highlighted.

Table 1. Benefits Criteria and Subcriteria

Criteria	Subcriteria	Relative Priority
Economic	Defense Industry	0.0209
	Stable Environment for Global Trading	0.0838
National Security	**Anti-Terrorism**	**0.1274**
	Eliminate Potential Nuclear Threat	**0.5096**
Political	**Improve U.S. Influence in Asia**	**0.1033**
	Positioning For Future Negotiations	0.0517
	Stable Global Political Environment	**0.1033**

Each of the most important subcriteria (in bold letters in Table 2) contains a subnet. Figure 3 is the subnet containing the alternatives and actors involved and the potential interactions.

Opportunities Subnet:

Unlike the benefits subnet, there were no subcriteria in the opportunities subnet (see Figure 4). Therefore, determining which criteria needed subnets required only looking at the priorities of each criterion. Table 2 shows the opportunities criteria and the priorities of the two criteria that have subnets (highlighted).

Table 2. Opportunities Criteria

Criteria	Relative Priority
Improve U.S. Trading Relationships	0.1143
Improve U.S. Image	**0.2802**
Step Towards World Peace	**0.4699**
Enhance Political Alliances	0.1356

Figures 5 and 6 contain the subnets under the opportunities criteria.

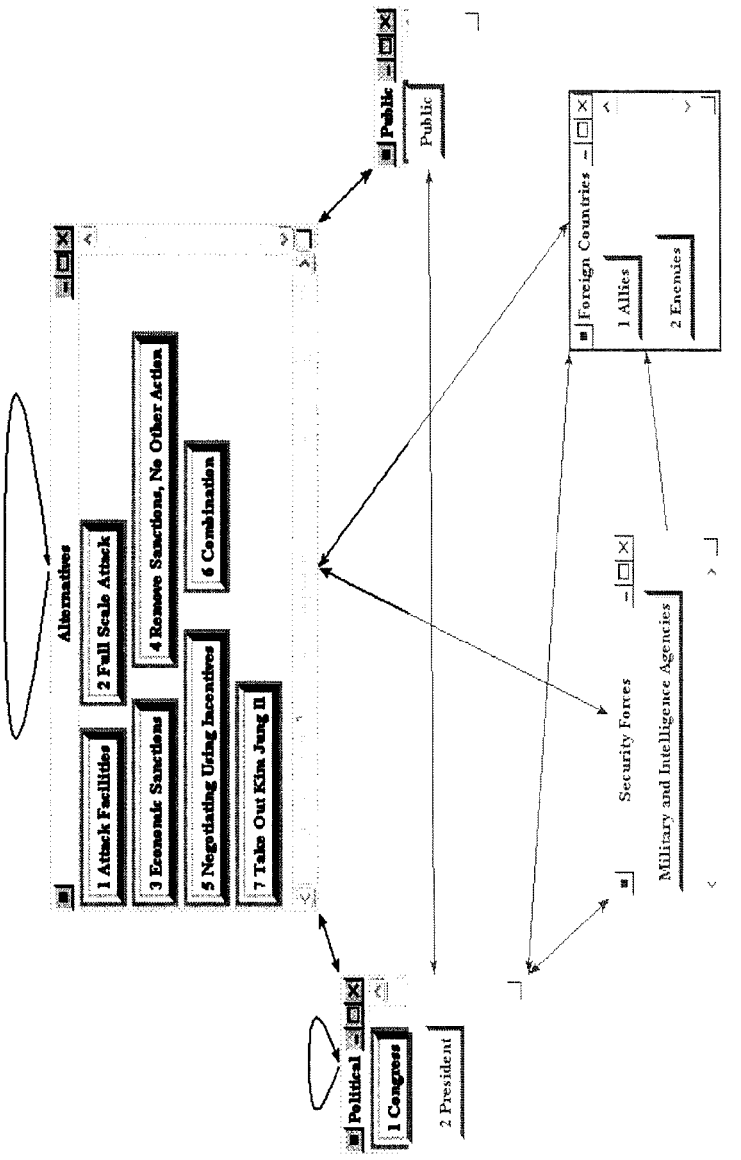


Figure 3. Subnet under Benefits – Antiterrorism/ Eliminate Potential Nuclear Threat/Stable Global Political Environment

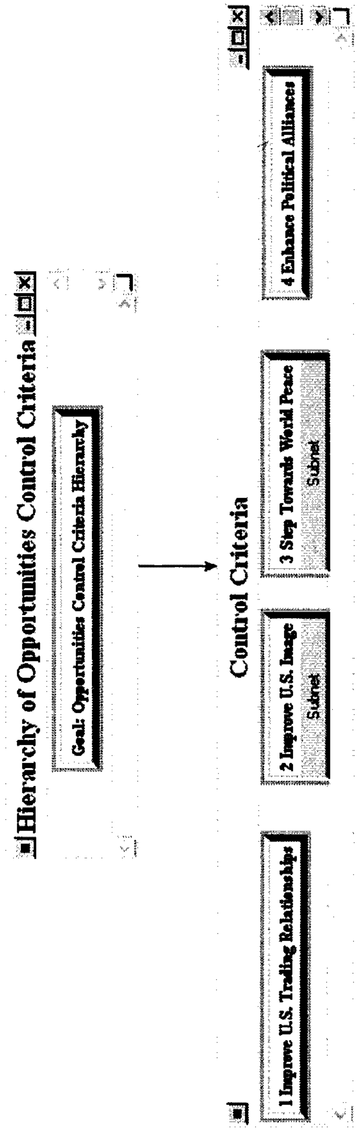


Figure 4. Hierarchy of Opportunities Control Criteria

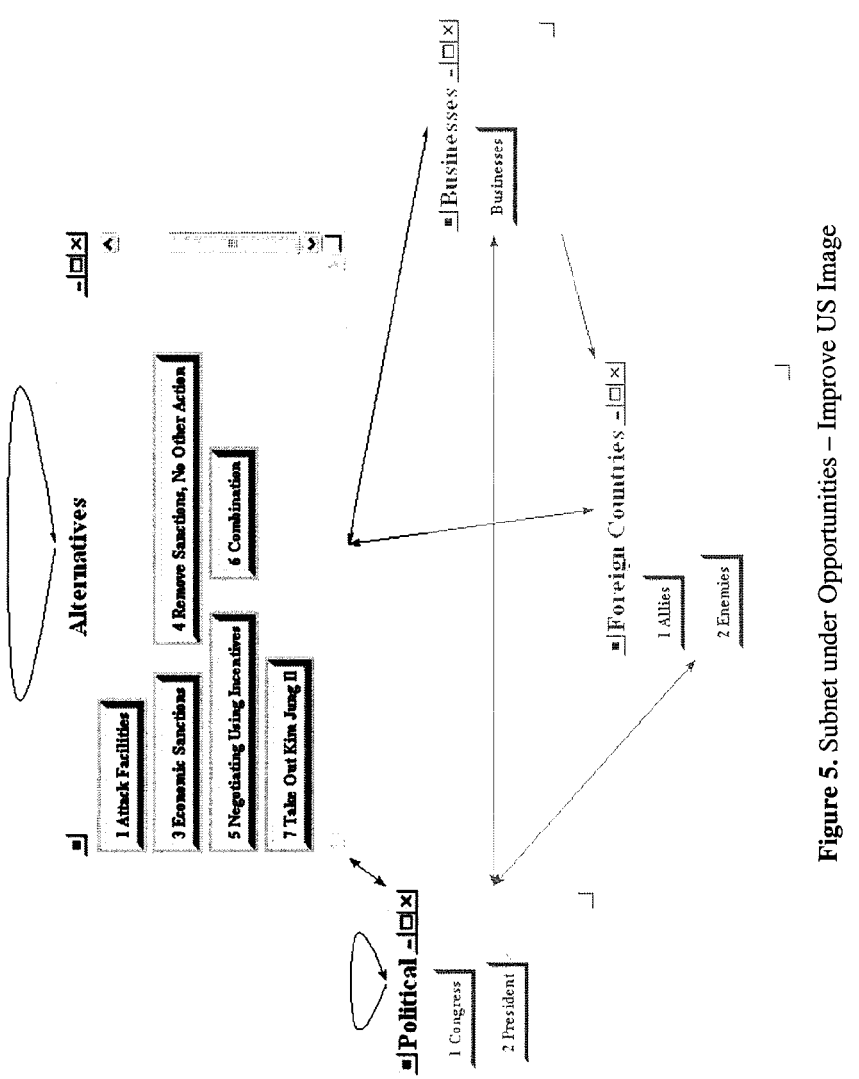


Figure 5. Subnet under Opportunities – Improve US Image

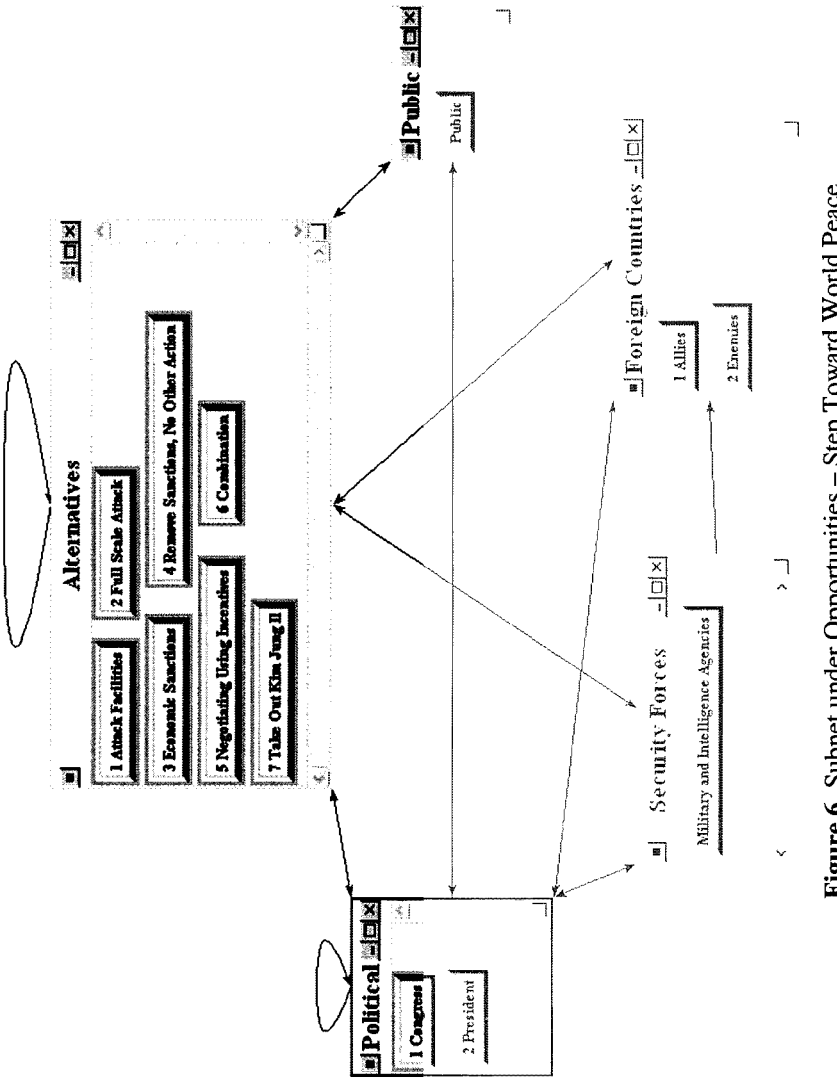


Figure 6. Subnet under Opportunities – Step Toward World Peace

Costs and Risks Subnets:

The relative priorities under the costs (Figure 7) and risks (Figure 12) control hierarchies were determined in the same manner as they were under the benefits and opportunities hierarchies. Tables 3 and 4 show the criteria, subcriteria, and priorities in these subnets. The subcriteria that have subnets are highlighted.

Table 3. Costs Criteria and Subcriteria

Criteria	Subcriteria	Relative Priority
National Security	**Diversion of Security Forces**	**0.1342**
	Loss of Life	**0.1342**
Economic	**Immediate Cost**	**0.1825**
	Ongoing Cost	**0.3315**
	Opportunity Cost	0.1004
Political	Foreign Relations	0.0879
	Public Concern	0.0293

Figures 8-11 show the subnets under the costs control hierarchy.

Table 4. Risks Criteria and Subcriteria

Criteria	Subcriteria	Relative Priority
National Security	**Increased Terrorism**	**0.0910**
	Nuclear War	**0.4552**
Economic	Destabilized Trading Environment	0.0279
	Damage to Trade Relationships	0.0558
Political	U.S. Reputation	0.0459
	Damage to Existing Alliances	**0.0918**
Social	Unrest Over War	0.0774
	Anxiety Over Nuclear Threat	**0.1549**

Figures 13-16 show the subnets under the risks control hierarchy.

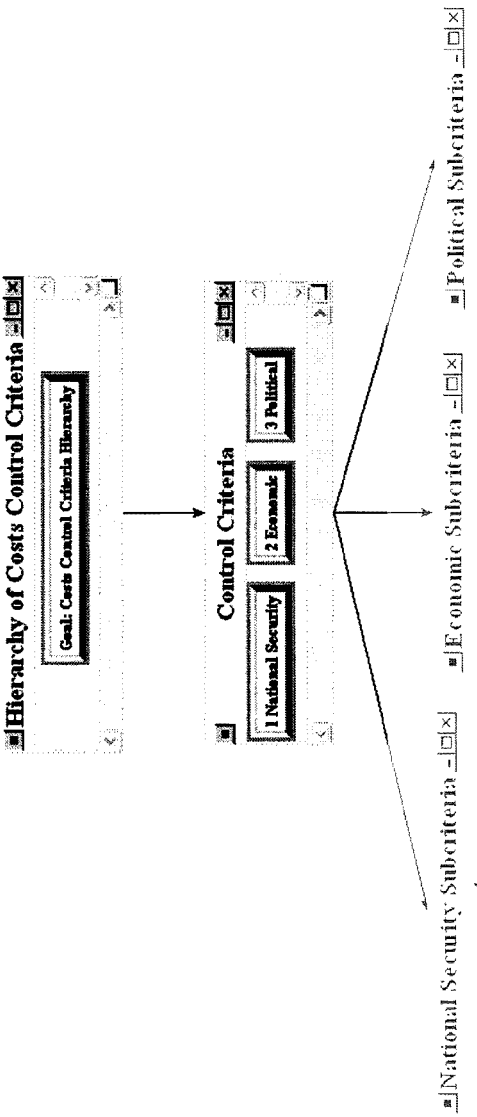


Figure 7. Hierarchy of Costs Control Criteria

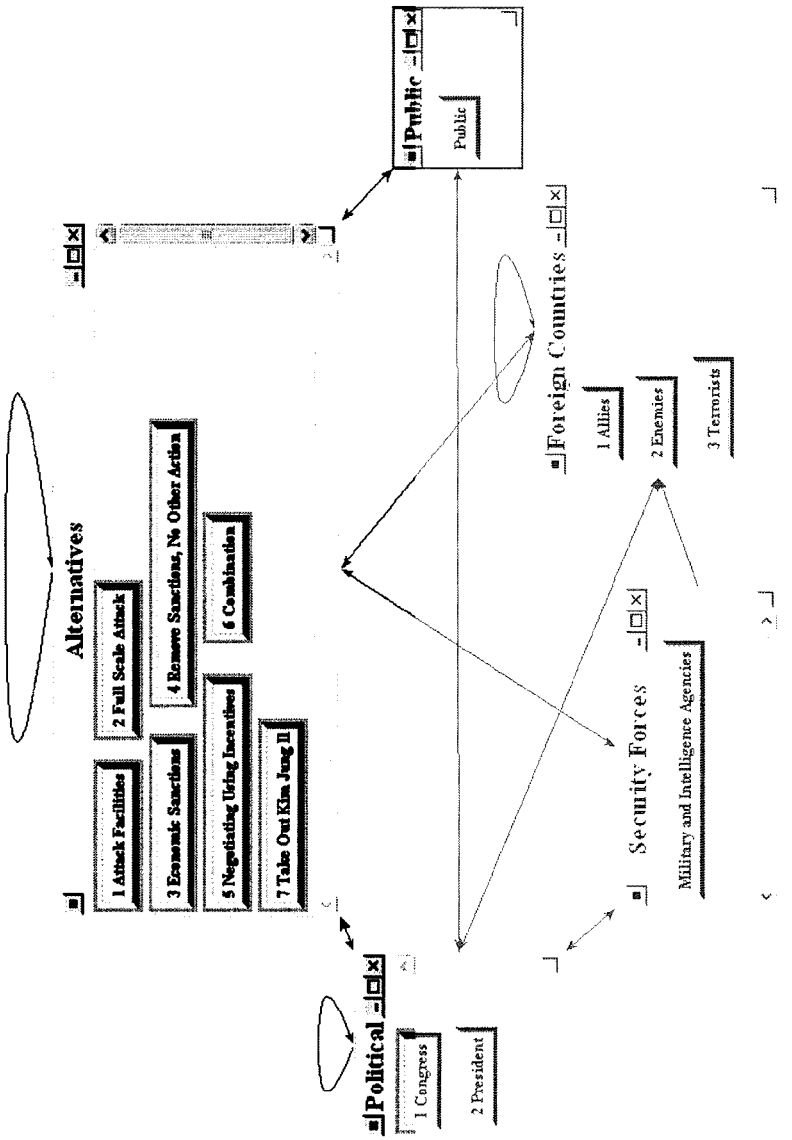


Figure 8. Subnet under Costs – Diversion of Security Forces

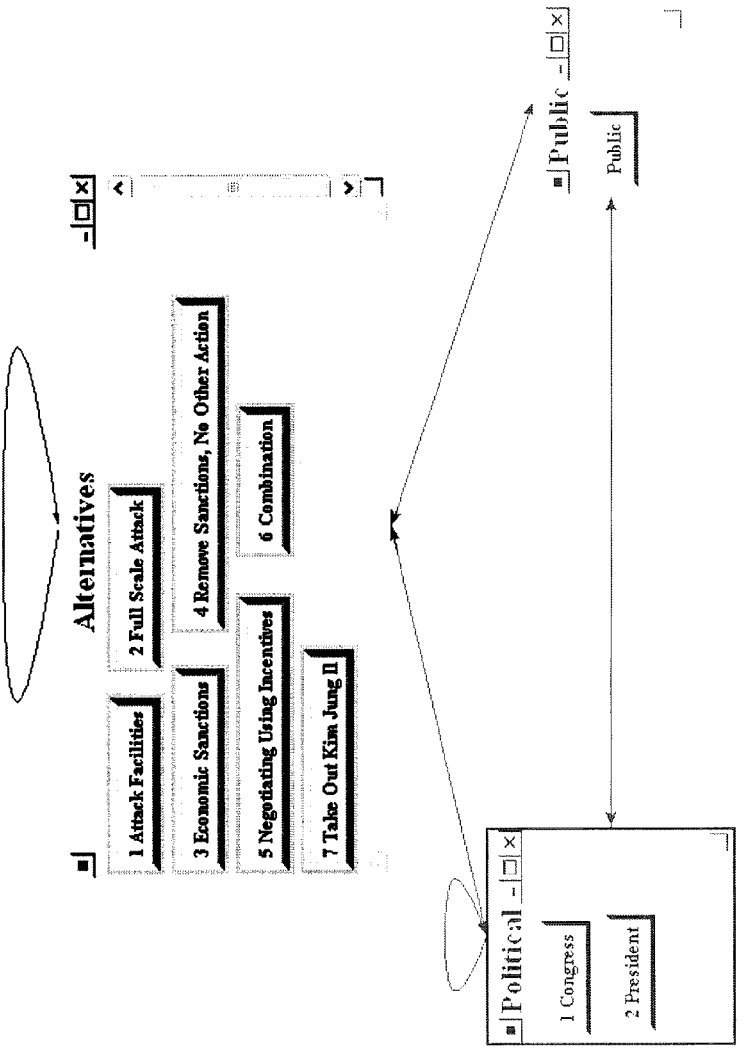


Figure 9. Subnet under Costs – Loss of Life

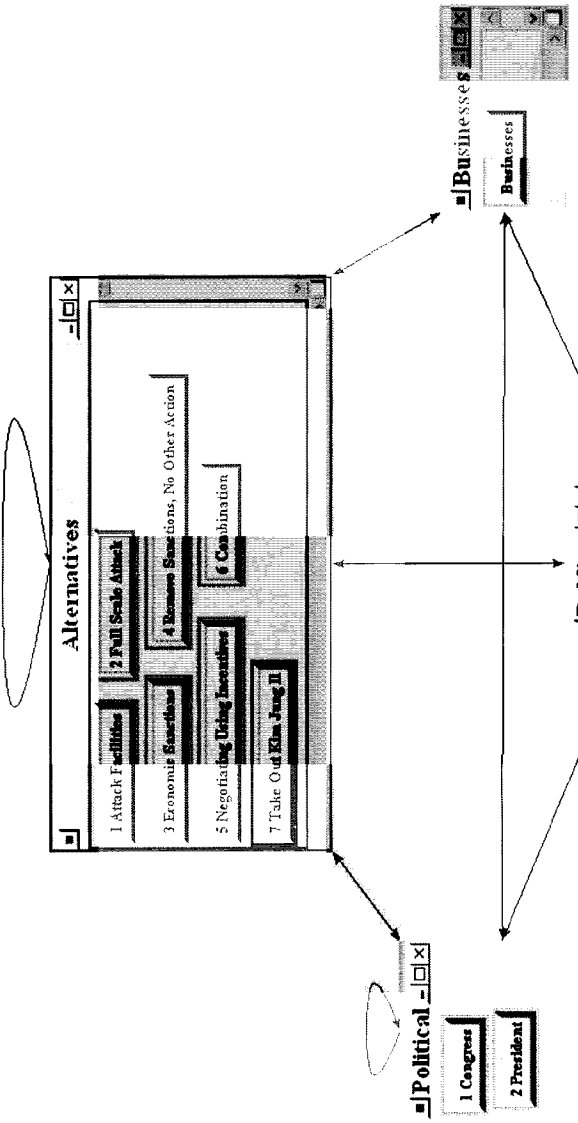


Figure 10. Subnet under Costs – Immediate Costs

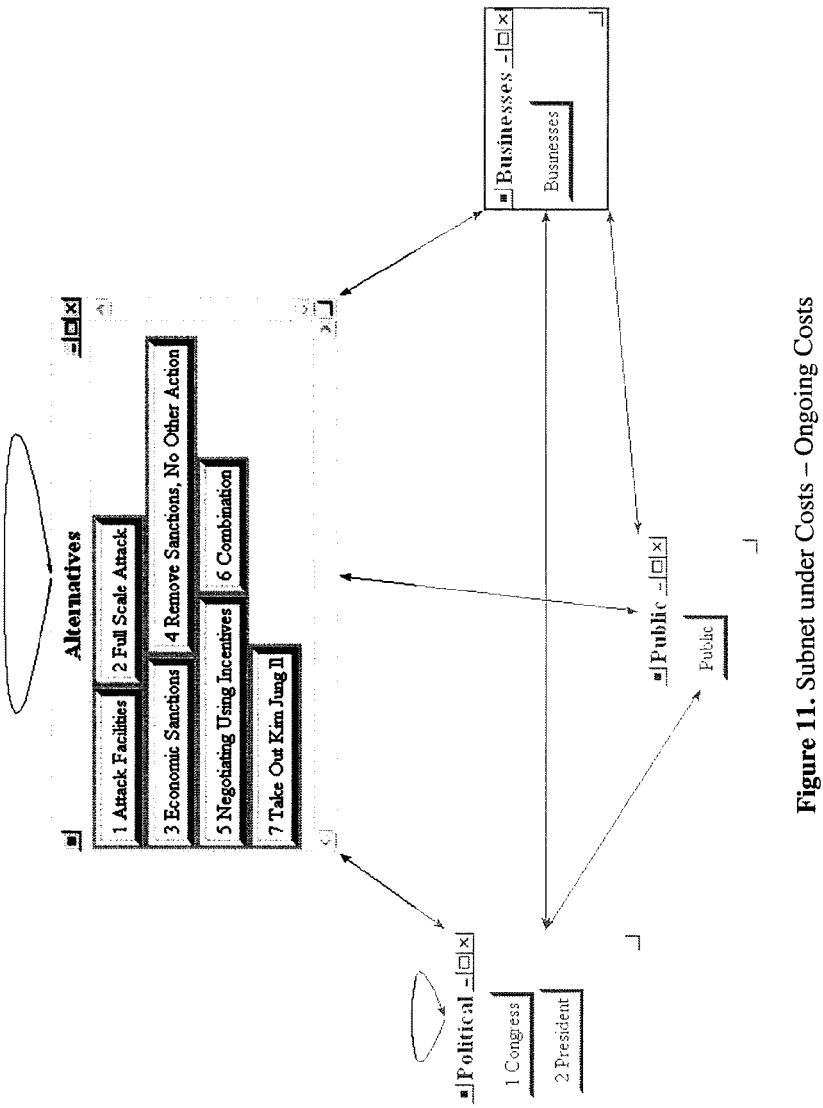


Figure 11. Subnet under Costs – Ongoing Costs

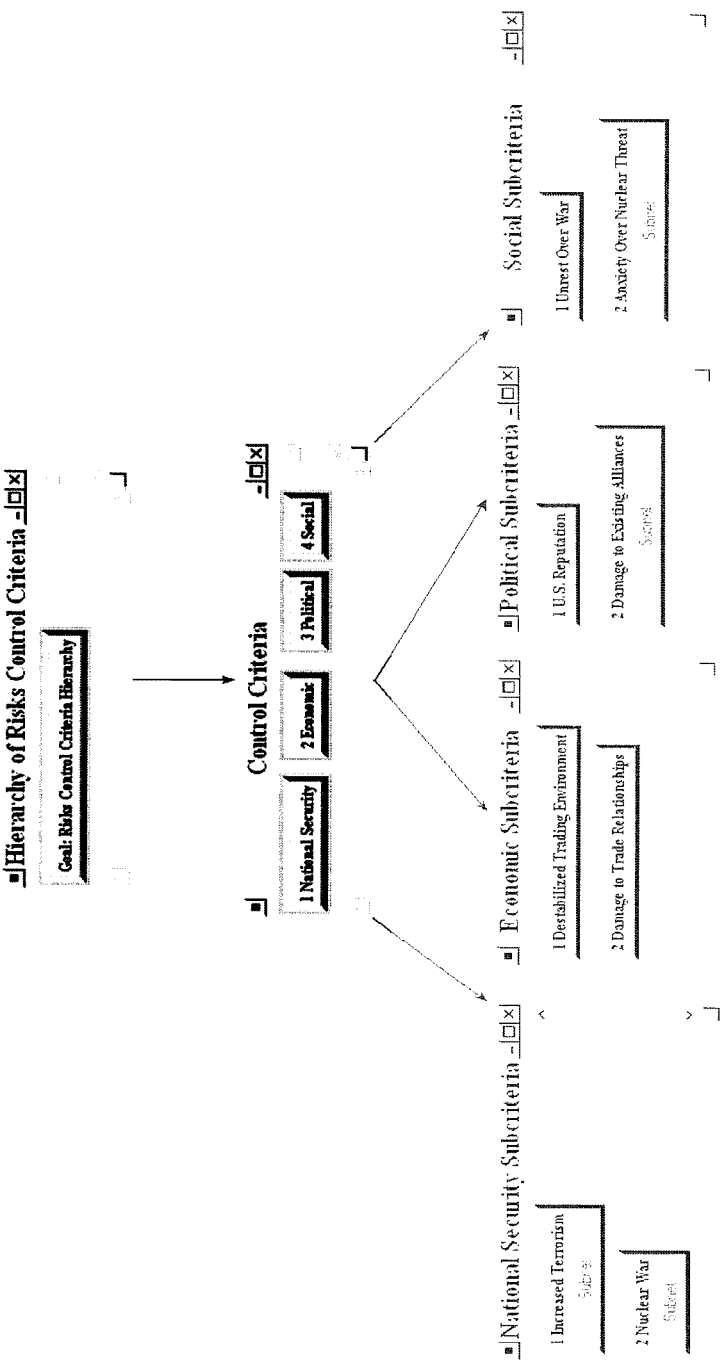


Figure 12. Hierarchy of Risks Control Criteria

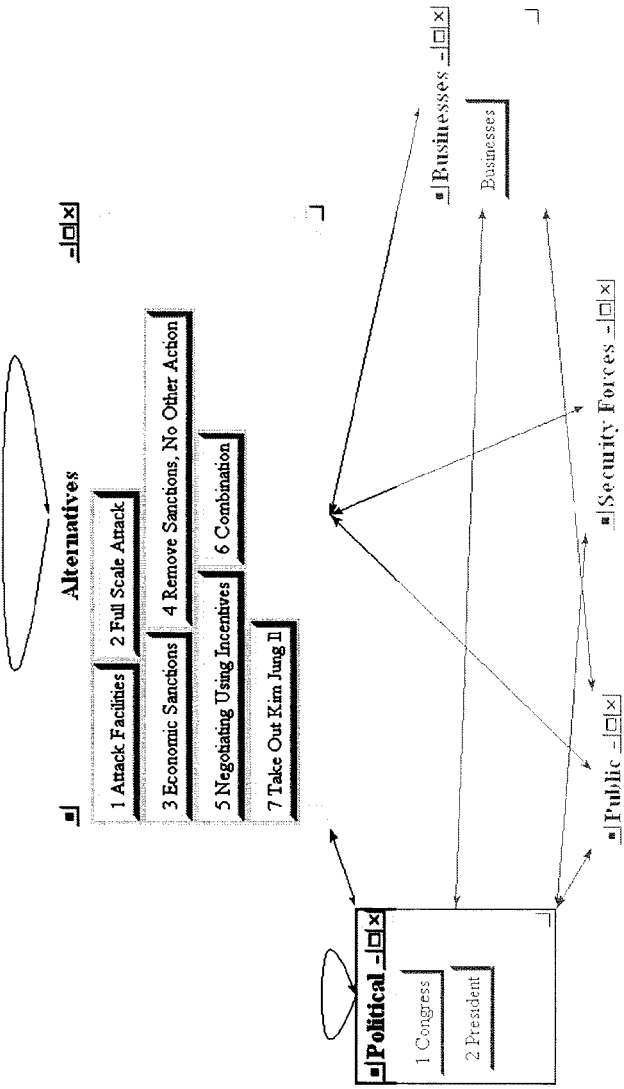


Figure 13. Subnet under Risks – Increased Terrorism

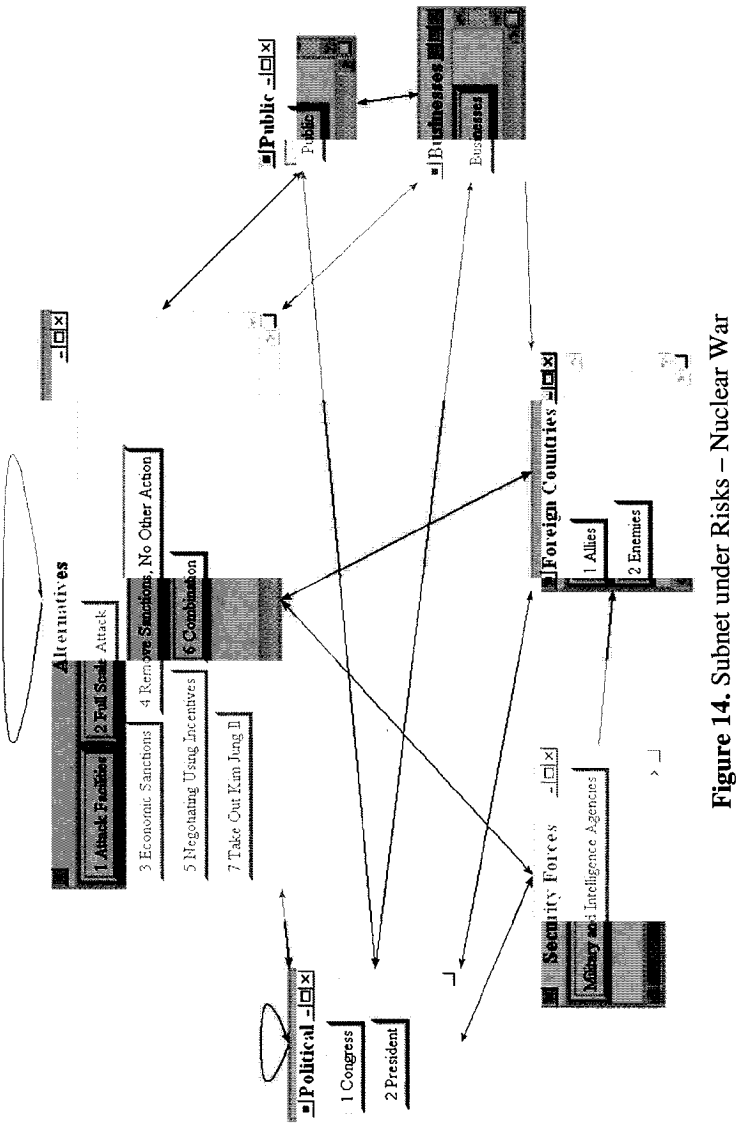


Figure 14. Subnet under Risks – Nuclear War

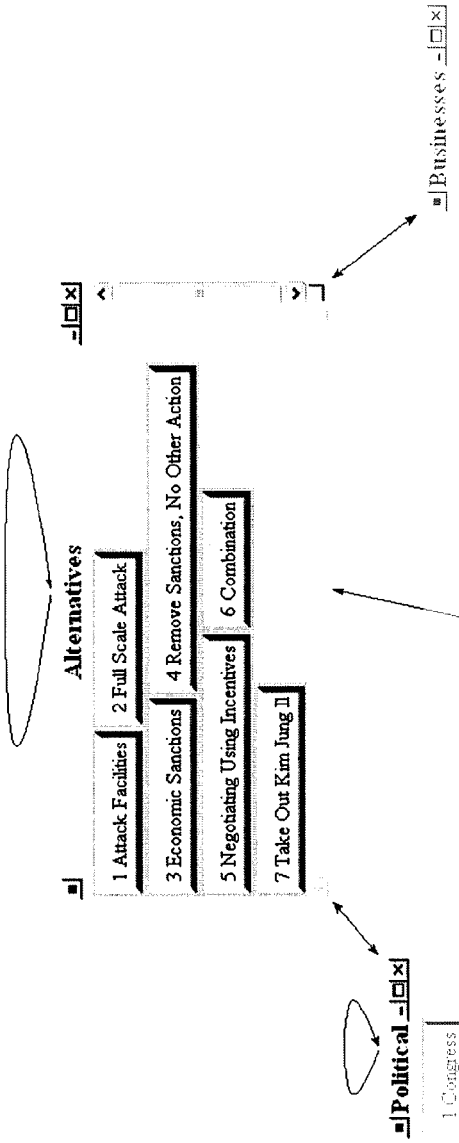


Figure 15. Subnet under Risks – Damage to Existing Alliances

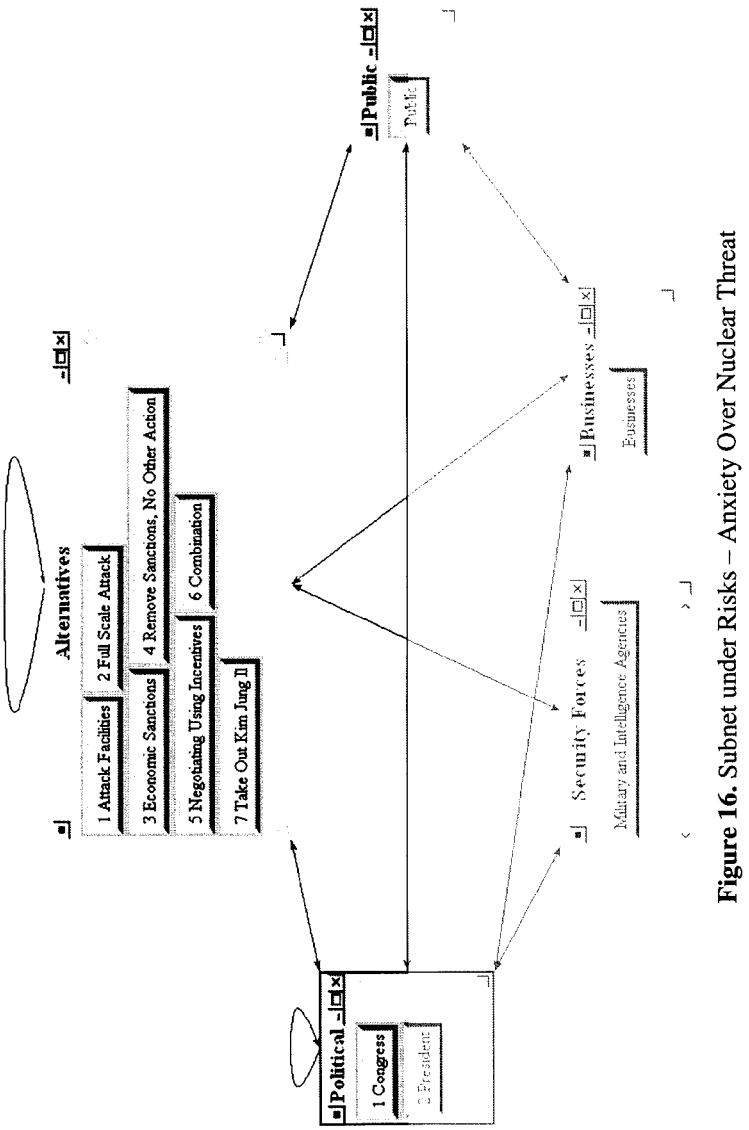


Figure 16. Subnet under Risks – Anxiety Over Nuclear Threat

4. RATING BENEFITS, OPPORTUNITIES, COSTS AND RISKS

Three strategic criteria were used in the model (See Figure 1) to rate the benefits, opportunities, costs and risks. Two of them were broken down into subcriteria. We have:

Economic
Political: With two subcriteria
- World Reaction
- Political Stability of Region

Social: With two subcriteria
- Effect on U.S. Citizens
- Effect on Citizens of Other Nations

Table 5 shows the ratings and priorities of benefits, opportunities, costs and risks. Under each criterion, there were five possible ratings:

- Extremely Low
- Low
- Medium
- High
- Extremely High

It should be noted that the priorities for costs and risks were much higher than the priorities for benefits and opportunities leading to negative outcomes. This makes sense given that the goal of dealing with the North Korean nuclear weapons threat is more about avoiding bad consequences than it is about achieving positive results.

Table 5. BOCR Priorities

	Economic	World Reaction	Political Stability of Region	Effect on US Citizens	Effect on Citizens of Other Countries	**Normalized Priorities**
	0.4000	0.3000	0.1000	0.1500	0.0500	
Benefits	Medium	High	High	Low	Medium	**0.1959**
Opportunities	Medium	Medium	High	Low	Low	**0.1519**
Costs	Extremely High	High	High	Medium	Low	**0.3484**
Risks	High	High	Extremely High	High	Medium	**0.3037**

Intensities:	Extremely High	High	Medium	Low
	1.0000	0.5574	0.2963	0.1564

4. RESULTS

Under both the benefits and opportunities subnets, Combination was the alternative that ranked highest. Under costs and risks, Full Scale Attack was the alternative that ranked the highest. Tables 6 show the results of each subnet.

Table 6. BOCR Results

Alternatives	Benefits	Opportunities	Costs	Risks
1 Attack on Facilities	0.5277	0.3277	0.5953	0.6599
2 Full Scale Attack	0.3011	0.1919	1	1
3 Economic Sanctions	0.7038	0.5685	0.1188	0.1774
4 Remove Sanctions, No Other Action	0.3891	0.4096	0.1231	0.2346
5 Negotiation with Incentives	0.7401	0.9052	0.1810	0.1700
6 Combination	1	1	0.1527	0.1685
7 Take Out Kim Jung Il	0.4446	0.3774	0.6278	0.5889

The overall results were calculated using two different formulas. Table 7 shows the results obtained using the multiplicative and additive negative formulas. Since the additive negative formula allows for negative results, Take Out Kim Jung Il, Attack Facilities, and Full Scale Attack all had negative values.

Table 7. Results Found Using Additive Negative Formula

Alternatives	BO/CR	bB+oO-cC-rR
1 Attack on Facilities	0.4402	-0.2546
2 Full Scale Attack	0.0578	-0.5640
3 Economic Sanctions	**18.9827**	**0.1290**
4 Remove Sanctions, No Other Action	5.5171	0.0243
5 Negotiate with Incentives	**21.7717**	**0.1678**
6 Combination	**38.8732**	**0.2435**
7 Take Out Kim Jung Il	0.4539	-0.2531

Both approaches gave the same results showing the alternatives ranked from best to worst as follows:

- Combination
- Negotiate with Incentives
- Economic Sanctions
- Remove Sanctions, No Other Action
- Take Out Kim Jung Il
- Attack on Facilities
- Full Scale Attack

5. SENSITIVITY ANALYSIS

Sensitivity analysis was performed to determine how sensitive the results were to changes in the priorities of benefits, opportunities, costs, and risks. Looking at benefits, no matter what value they had, the results still indicated that the best course of action was Combination. When sensitivity analysis was done on opportunities, Combination was also found to be the best alternative regardless of the priority of opportunities. Looking at costs, Combination was found to be the best alternative as long as costs had a priority less than 76%. Looking at risks, Combination was the best alternative regardless of the priority of risks. Figures 17-20 show the sensitivity analysis graphs for benefits, opportunities, costs, and risks.

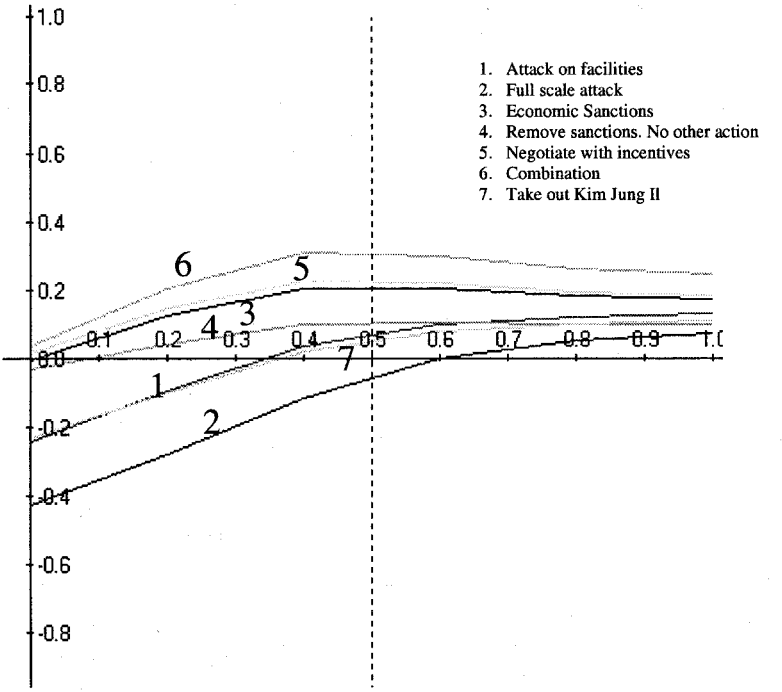


Figure 17. Sensitivity Analysis for Benefits

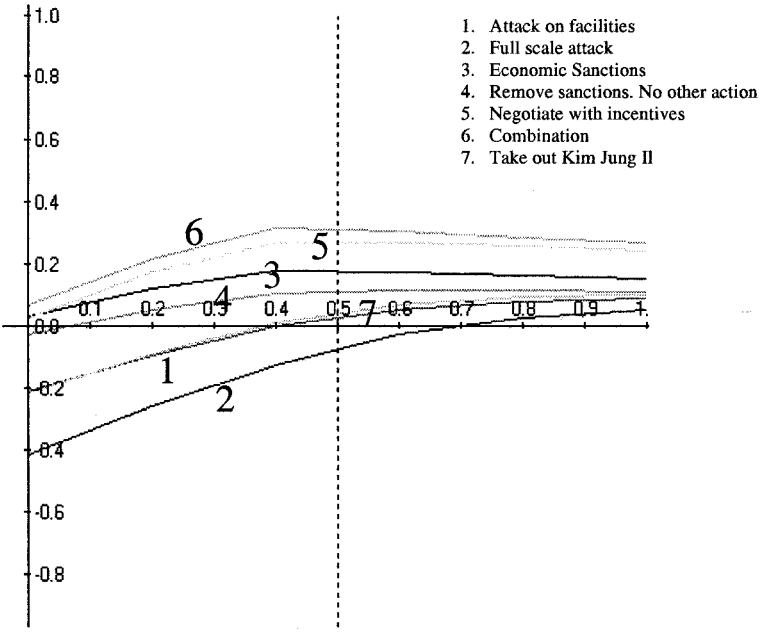


Figure 18. Sensitivity Analysis for Opportunities

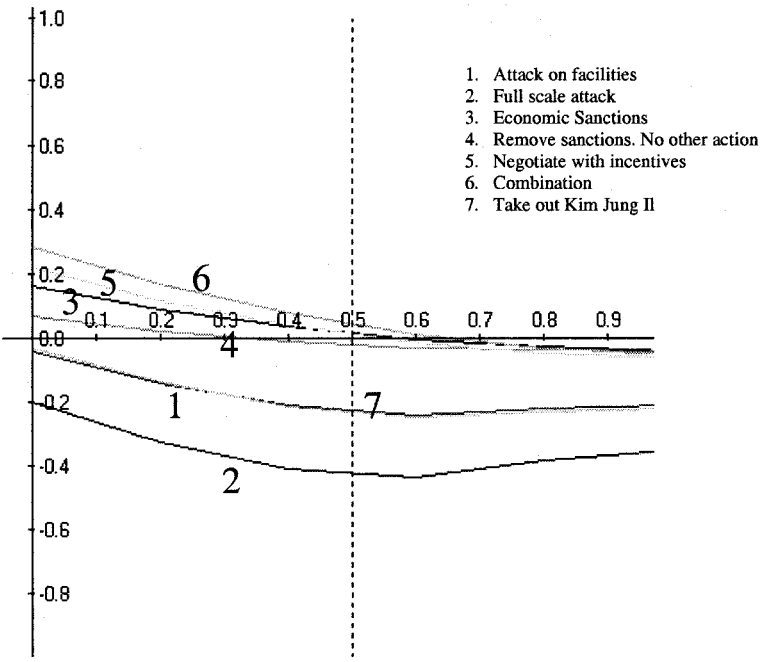


Figure 19. Sensitivity Analysis of Costs

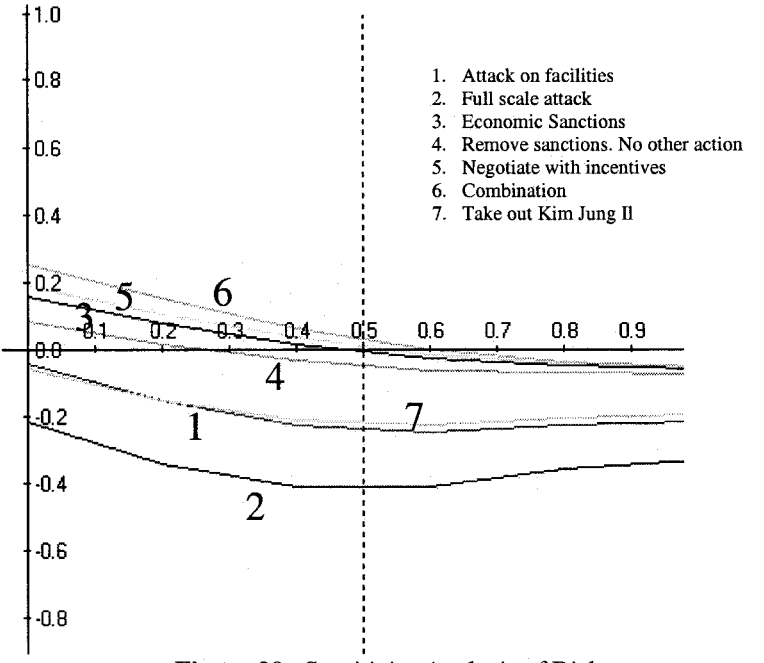


Figure 20. Sensitivity Analysis of Risks

6. CONCLUSION

Current United States policy towards North Korea has so far not been successful in eliminating the nuclear threat. To resolve the problem, the United States may need to take a more active role in dealing with North Korea. When weighting all of the factors, it appears that the best option for dealing with North Korea is to negotiate using both the threat of sanctions and the offering of incentives.

CHAPTER 13

CRITERIA FOR EVALUATING GROUP DECISION-MAKING METHODS

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1. INTRODUCTION

In this paper we are concerned with the development of criteria for evaluating different methods of group decision-making that range from the strictly technical, to the psychophysical and social, and finally, to the logical and scientific. Our purpose is to identify similarities and differences with the aim of showing from such wide consideration which method is more attractive, and is likely to gain greater attention both in academia and in practice. Its outcome would survive outside influences because it makes possible incorporating such influences in its structures, and assessing their relative impact on the outcome in a way that does not tax one's intelligence to accept its procedures, nor do these procedures alienate the user. Needless to say, all users are born, potentially expert, decision-makers. Eventually all MCDM methods need to be extended to allow for dependence of criteria on alternatives so that the user is not forced to cast her/his problems and think in ways that may seem artificial because of strong assumptions about independence that cannot be adhered to strictly. Urli and Nadeau [1999] have observed that the future of MCDM is "subject to questions and debate among its researchers: what is the evolution of the field? What is its structure? Is it integrating new topics?" thus giving us a slant on the possibility of an evolving set of criteria for evaluation as well. In this regard, Corner, Buchanan, and Henig (2001) have talked about dynamic interaction between criteria and alternatives that can lead to expanding the structure of a decision with increased understanding. Da Costa and Buede (2000) have written about dynamic decision-making and how to deal with optimizing decisions in the framework of dynamic decision networks, again taking a long time horizon in thinking about decision making.

The main object of this work is not so much about identifying and exhaustively summarizing all MCDM methods as it is about developing a way of examining, with a broad set of criteria, what to look for in judging the merit of a decision making approach. Undoubtedly, what we have here needs to be altered and further expanded to take into consideration factors that deal with interaction between user and method, outcome and method, and user and outcome. A scientific undertaking of this kind may be helpful in improving and expanding MCDM research thrusts to deal with complex decisions.

One can delve into a diversity of ramifications involved in decision- making. Such ramifications may deal with intellectual, psychological, or environmental effects regarding the comfort of a decision maker when making a decision for example. They can also deal with improving intuitive understanding and practice as appropriately pointed out by Wierzbicki (1997). Here we have to confine our attention to general criteria concerning the technical merits of MCDM methods and how well they address their subject matter.

"Should a decision analyst primarily support a client's decision process as it is or should he reshape it and teach the client how to make a decision in another way? Which is the proper balance between the two in different situations? Perhaps it does not matter if the input from a client to a multi-criteria decision model is compatible with that model or not?" writes Svenson (1998) adding further complexity to the idea of evaluation methods. A client may be pleased with a simple method because he is unaware of the complexity involved in the process of eliciting and synthesizing judgments and may even strongly advocate the best outcome unaware that a richer structure and better knowledge and interaction can produce a better decision. This further adds to the difficulty of choosing additional criteria to compare methods.

There are numerous useful criteria proposed in the literature to judge group decision-making. We use them as a basis for establishing new criteria for judging group decision support methods. We identify and briefly describe several of the well-known methods in decision-making. We define various intensity measures on each of the new criteria. We then evaluate each of these methods by assigning it the intensity that describes it best on each criterion, explaining briefly why that intensity is appropriate for the method. In this manner, the methods are compared and contrasted with respect to each criterion, and for lack of a better and more general way to structure the problem, a table is developed that can be used to obtain an overall rating of the methods, although we have refrained from doing it here as we do not wish to offend the developers and the users of one or the other of these methods.

2. CRITERIA FOR GROUP DECISION MAKING METHODS

Rubin [Swap and associates, 1984] proposed six quality indicators for group decision making that address both achievement and maintenance goals [Brightman; 1980, 1988): *efficiency, careful development and analysis of alternatives, fairness, member satisfaction and morale, leadership effectiveness,* and *growth over time.* These indicators are developed from a group process point of view, and need to be translated into another set of indicators before they can be used as criteria for evaluating the methodologies that facilitate for a group to excel on those quality indicators. We exclude efficiency from our analysis because it is highly dependent on the way the group is organized and led. We perceive growth over time as learning. We assume that a method that

addresses group maintenance (leadership effectiveness and learning) would also ensure member satisfaction and morale; hence we do not consider the latter as a criterion explicitly.

First, a general method for group decision-making must provide a facilitator with the means to lead the group to achieve and maintain its goals. The method must also assist the facilitator in enhancing individual and group learning, both single loop or small "l" learning and double loop or big "L" learning [Argyris, 1977, 1994; Pascale, 1991]. It addresses the first if it enables the group to solve problems of implementing organizational policies and achieving the goals of the organization through incrementally, based on past performance and knowledge. It addresses the second if it facilitates questioning the underlying assumptions of those policies and goals through breakthrough shift of knowledge. Systematic and comprehensive development of alternatives means that the group must not view a problem from a scope too narrow to ensure a meaningful solution or too broad to ensure controllable actions. It also means that the group must be able to identify a set of distinct alternatives from a level of abstraction that is adequate for the group. For example, a group of top executives would view a problem from a higher level of abstraction than would a group of operational managers because they have a much wider choice space from which to draw controllable alternative courses of actions. Careful analysis of alternatives requires the group to work with a model/structure [Reagan-Cirincione, 1994] with the appropriate breadth (for relevance) and depth (for precision). A successful analysis depends on faithfulness of judgment elicitation, psychophysical applicability, and the depth of the analysis. For example, in some methods one must first accept the premise that eliciting judgment by comparing two alternatives with respect to a certain property would produce the most faithful representation of one's tacit preference relations. Faithful judgment can be obtained if: (1) it is expressed directly by the decision maker, rather than derived from some other form of judgments, (2) it is not clear to the decision maker as to how that particular judgment would ultimately affect the outcome and hence would not play games with it to influence the outcome, thus preventing strategic judgment [Dummett, 1984], and (3) the decision maker has the choice to express preference relations numerically (as a minimum for representing objective measurement) or verbally (for representing perception or feeling), or even graphically. Interestingly, Larichev and Brown [2000] have examined the merit of making decision approaches to improvise ways to create a new alternative that is better than the existing ones. Depth of analysis means how well an analytical method provides the means to guide a decision-makers' thinking to ensure the validity of the outcome. It includes, for example, having a feedback mechanism for making changes and adjustments or directing the decision-maker to an expert or looking for specific information.

Fairness is addressed both during group interaction, and when the variety of information or judgments from individuals must be mathematically aggregated into one judgment for the group. For this criterion, we are only concerned with the method of aggregation, since group discussion is likely to be controlled by

the facilitator. A strong condition for a successful decision theory with regard to resource allocation is that it often needs to make it possible to separate the alternatives with cardinal numbers than simply order them. The group members themselves may need to be weighted as to the reliability of their opinions. Other actors or stakeholders who may be affected by the implementation of the decision often need to be considered, and a successful method needs to have a way to include their judgments.

Most significantly we add, a method must be generally *applicable, valid* (*can be scientifically validated*), and *reflects the truth* advocated by those who provide the judgments. From such considerations, one would be concerned with such issues as: (1) Is the method applicable to conflict resolution? (2) Does it apply to intangibles in the same way it does to tangibles? (3) Does it have mathematical validity and generality, and is it supported with axioms and theorems? (4) Can the method be applied to psychophysical measurement? and (5) Is the outcome valid, ensuring, for example, reliability in prediction?

Applicability to conflict resolution means that the method must provide a way for each conflicting party to evaluate the costs and the benefits of giving up some of what it has, in return for getting what it wants from the other party. Applicability to intangibles involves inclusion, and measurement of, the multidimensionality of the factors involved. Mathematical validity and generality calls for formal mathematical representation of the logic and reasoning behind a theory and the economy of additional assumptions required for its generalization. Psychophysical applicability means that an analytical method must deal with the measurement of relationships between the physical attributes of stimuli and the resulting sensation reflecting diminishing response to increasing stimulus such, for example, as that described by the Weber-Fechner law. Validity of the outcome involves the accuracy of the outcome in predicting situations. One needs to be careful, however, to define what constitutes a prediction situation. In an experimental study, Schoemaker and Waid [1982] showed that guesswork with direct estimation of the rank of multi-criteria objects produces a very different ordinal ranking than the cardinal ranking produced by another method.

The following 16 criteria are used to compare and contrast the various methods:

Group maintenance: leadership effectiveness.

We assume that all group methods enhance leadership effectiveness. We use a democratic leader's characteristics as criteria for leadership effectiveness, assuming that the group mostly works in moderate situational control in terms of leader-member relations, task clarification, and position power [Lewin, Lippit, and White, 1939; Fiedler, 1973]. A method is rated low if it is highly technical or does not involve much interaction and where leadership is of a little concern, medium if it provides no more than structure to facilitate group leadership, and high if it also provides other collaborative tools and the necessary control

mechanism to guide the facilitator's leadership actions in pursuing the group's achievement and maintenance goals.

Group maintenance: learning

It is assumed that objective knowledge that is widely accepted and agreed upon, is considered less important by the people involved in the group than what they know from their experience relevant to the issues and what they learn by problem solving within the group. A method is rated low if it advances technical learning that has little to do with the group member's subjective values, medium if it improves understanding with regard to cause-effect relations in a problem (but actions may not be clear, single loop or small 'l' learning only, or, it does not provide clear evaluation of alternatives), high if it facilitates both single and double loop learning, or small "l" and big "L" learning (leading to action), and very high if it also enables one to produce the necessary material to facilitate learning beyond the membership of the group.

Problem abstraction: scope

The need for problem abstraction or definition is inherent in any decision-making, therefore this indicator is assumed to be addressed by all methods. The question is whether a method explicitly addresses this issue or not. Voting is an exception for which alternatives are always given, hence problem abstraction is not applicable and this method is rated NA. A method is rated low if it does not propose a specific technique and does not involve problem analysis that enhances the scope of abstraction, medium if its technique creates boundaries that limit group thinking, or, if it does not propose a specific technique but involves problem analysis that serves as feedback to broaden problem abstraction, and high if double loop learning is explicitly addressed.

Problem abstraction: development of alternatives.

It is generally assumed that the alternatives are not given to the group; hence any method involving problem structuring must go through a process of identifying alternatives. It is assumed that multi-criteria methods require a process of generating alternatives that allows a certain degree of interaction among group members. It is also assumed that a method for enhancing problem abstraction leads to a set of alternatives. Again, voting is an exception because a set of alternatives is always given. A method is rated NA if the alternatives must be given, low if it does not provide a specific technique for identifying alternatives, medium if it ensures a free wheeling environment without group interaction, or, if it generates incremental alternatives (it is assumed that innovative change is more preferred to incremental change), high if it ensures a free wheeling environment as well as group interaction but no requirement that the alternatives selected satisfy certain properties or requirements (e.g., distinct or independent), very high if it is also based on challenged assumptions, if it systematically generates alternatives, or, if it requires the alternatives to satisfy certain properties to ensure the validity of the outcome.

Structure: breadth

A structure is said to be broad if it has many distinct elements (criteria) that are assumed to be independent of each other. A problem that is modeled by more than one such structure is considered to be even broader. A method is ranked NA (not applicable) if it does not involve problem structuring, low if the method allows only one element (direct comparison), medium if the method creates a constraint with respect to the number of elements, and high if there is no such constraint.

Structure: depth

A structure is said to be deep if each element is broken down into sub-elements, each sub-element into sub-sub-elements and so on down to the most detailed elements. A method is ranked NA if it does not involve structuring, low if it allows only one element, medium if it creates a constraint with respect to the number of elements, and high if there is no such constraint.

Analysis: faithfulness of judgments

A method is rated NA if it does not involve problem analysis, low if it does not include intensity of preferences, medium if it involves direct assignment of numbers to represent intensity on an scale that is assumed but not derived from more basic and common understanding, high if it is derived from some other judgments carefully elicited, very high if it is elicited in the most elementary way (pairwise comparison with respect to a property), expressed in a way that fits the decision maker best (numerically, verbally, or graphically), or, if it is by design an objective method, or, if it is continuously improved.

Analysis: breadth and depth of analysis (what if)

A method is rated NA if it does not involve problem analysis, low if it allows judgment, but not analysis, medium if the depth of analysis is constrained by the method's structure, high if it provides the means for careful thinking (but it is difficult to review previous analysis), and very high if it facilitates careful thinking and review.

Fairness: cardinal separation of alternatives

This indicator is applicable only to methods that involve aggregation of judgments of individual members. Alternatives can only be treated either fairly (high) or not fairly (low). A method is evaluated according to its consistency with the impossibility problem intrinsic in ordinal group aggregation. An aggregation method is rated low if it uses an ordinal scale of measurement and high if it uses an interval, a ratio, or an absolute scale. A method is rated NA if it does not involve judgment aggregation.

Fairness: prioritizing of group members

This indicator is also applicable only to methods that involve aggregation of individual judgments. Voting theories usually operationalize fairness as equal treatment of the voters. With group decision-making, there may be

circumstances in which the group may want to apply the concept of fairness with unequal treatment of the individuals involved. For example, weights may need to be assigned to the members according to the relevance of their expertise or to their known previous contribution to the goal. A method is rated NA if it does not involve judgment aggregation, low if individual preferences are represented on an ordinal scale, medium if the preferences are represented on an interval or ratio scale, or an absolute (but the individuals must carry the same weight), high if it also provides a group with an option to treat group members unequally (but the weights are assigned arbitrarily), and very high if it provides a method to determine the weights as appropriately as the group wishes.

Fairness: consideration of other actors and stakeholders

This criterion is applicable only to methods that involve problem analysis. A method is rated NA if it does not involve problem analysis, low if addressing fairness to other actors that might be possible (but it is not yet made explicit in the method), medium if it addresses the issue explicitly but qualitatively, and high if it addresses the issue both explicitly and quantitatively.

Scientific and mathematical generality

A method is rated NA if it does not involve problem analysis, low if it does not involve any mathematics, medium if it involves mathematics that is not axiomatized, or, it involves multidimensional concepts that may be axiomatized differently by different researchers leading to a diversity of theorems, high if it is axiomatized with more or less unified conceptualization (but its generalization has considerable mathematical rigor), and very high if its theorems are axiomatized and generalizable in a natural and less taxing way by not requiring many new assumptions.

Applicability to intangibles

A method is rated NA if it does not involve problem analysis, low if it does not involve quantification of intangibles, or, simply assigns arbitrary ordinal numbers to intangibles, medium if it involves measuring intangibles on an interval or a ratio scale or an absolute (but must be represented by tangibles or intensities in absolute terms with no assigned priority, high if it involves measuring intangibles on an interval or a ratio scale or an absolute, but must be represented by tangibles or intensities in absolute terms with assigned priority), and very high if its measurement is applicable to intangibles and gives an assessment of their relative importance, both absolutely or relatively, as the user wishes.

Psychophysical applicability

A method is rated NA if it does not involve problem analysis, low if it does not address issues of stimulus-response so it appears relevant and not arbitrary, medium if it could but requires a complex model that may not be practical to develop or to apply, and high if it is psychophysically applicable.

Applicability to conflict resolution

A method must have an approach and perhaps also normative standards for best solution of a group conflict that is understandable, acceptable, practical, flexible, and has been demonstrated to work well in practice. Such a method would be rated high. However, secrecy makes it hard to use such an approach in a clear step-by- step fashion, and hence people often resort to less structured and less explicit methods. For this reason, an analytical method for dealing with conflict resolution is rated medium. A method that enables the conflicting parties to structure a comprehensive model and quantify the payoffs accurately is rated high.

Validity of the outcome (prediction)

A method is rated NA if it does not involve problem analysis, low if it uses ordinal measurement with no structural representation of a problem, medium if it uses cardinal measurement, but its main concern is computation, or, if it uses ordinal measurement with some problem representation, or, if it provides a rigorous model without measurement, high if it uses cardinal measurement, but mathematical validity sets limits on the structural representation of a problem, and very high if it uses cardinal measurement and no theoretical limit with respect to the structural representation of the problem.

3. GROUP DECISION MAKING METHODS

Couger [1995] provides a summary of most of the methods.

Structuring

Analogy and attribute association are methods for gaining fresh perspective on a problem to create an alternative space from which meaningful and controllable distinct alternatives are likely to be identified. They involve the use of key words from the original formulation of a problem as the means to identify relations between the otherwise unrelated analogy/association and the original problem.

Boundary examination is a conscious effort to openly challenge and restructure the underlying assumptions that prevent one from seeing a problem from a broad perspective. The progressive abstraction method increases problem abstraction implied in the goal step by step. This, along with the first, differs in technique but their purpose is so similar that we do not consider them as different methods.

Brainstorming [Osborne, 1957] is based on the premise that deferred judgments enhance creativity and that oral communication diminishes it. Its modification includes, e.g., brainwriting (generating ideas in writing), bug list and negative brainstorming (generating complaints to identify weaknesses), the Crawford blue slip method (independently brainstorms in response to a number

of questions that are related to a problem), and discussion among group participants as long as it is not judgmental.

Morphological connection is an attempt to broaden the space of alternatives not through problem abstraction, but from different combinations of problem attributes as in a hierarchy. Despite what the term may imply, this method is not designed for connecting or structuring different ideas related to a problem to make a decision.

Why-What's Stopping is proposed for formulating ill-structured problems [Basadur, Ellspermann, and Evans; 1994]. It consists of a series of diverging and converging ideas by seeking responses to the questions: "How might we..." (to elicit ideas on alternative solutions) "What's stopping us ..." (to provide narrower sub-problems for each response to the "How might we..." query), and "Why would we need to ..." (to ensure that we work on the right problem as stated in the "How might we..." query). The outcome of this process is a big picture of a problem, indicating relationships among problems and sub-problems; to help decision makers select the most meaningful problem area to work on.

Ordering and Ranking

Voting, as has been discussed at length in the previous chapters, elicits ordinal judgments and mathematically aggregates them into a group judgment. It is considered as a single criterion analysis since the individuals compare alternatives directly. For our purpose, interaction among members is considered irrelevant.

The Nominal Group Technique (NGT) [Delbecq, Van de Ven, and Gustafson; 1975] takes advantage of the positive aspects of brainstorming and brainwriting and structured communication that improves alignment of group members' perception of the problem without working towards concensus.

The Delphi method [Turoff, 1970; Linstone and Turoff, 1975; Gustafson, Shukla, Delbecq, and Walster, 1973] is similar to NGT except that the group members do not meet face to face. A great deal of preparation is required due to the nature of written communication.

Disjointed incrementalism is a method to select the best policy based on its incremental consequences. This method was proposed to deal with complex policy decisions, typically in the government, in which a holistic approach for policy decisions is either impossible or impractical. It has been argued that muddling through is a science.

Matrix evaluations refer to methods for presenting information to facilitate the evaluation of alternatives. It may describe factors and sub-factors involved in a problem with their ranking scores, or by providing the relative overall positions of alternatives in a multidimensional space. For example, various company products may be evaluated with respect to their market share and growth (BCG matrix) or various organizational improvements with respect to

their importance and imminence [Camillus and Datta, 1991]. These methods, however, do not provide a methodological way to arrive at a decision.

Goal programming is an approach to optimize a set of objective functions subject to constraints. However, it does not necessarily suggest decisions that optimize the objective functions [Ching and Ming; 1987]. It only yields decisions that "satisfice" [Simon, 1957]. The outcome is perceived as indicating trade offs that need to be made in terms of reducing a certain objective in return for an increase in some other objectives.

Conjoint measurement is concerned with predicting the values of a dependent variable by combining a set of independent variables in some functional form. The coefficients of the function are usually estimated by regression techniques. A conjoint analysis measure has been suggested for use as a numerical basis for estimating the priorities of a goal-programming problem [O'Leary and O'Leary, 1985].

The concept of outranking was developed by Bernard Roy based on Multiattribute Utility Theory (MAUT) principles with the motivation to improve efficiency without affecting the outcome while considering less information. The idea is to see whether there are enough arguments to decide that an alternative A_i is at least as good as A_j, while there is no essential reason to refute that statement. Researchers in this area have worked toward the satisfactory axiomatization of the concept, in which criterion prioritization has been their major preoccupation [Roy and Bouyssau, 1985; Vincke, 1989]. In the meantime, ten different methods have been developed to apply the concept. They differ in how the reason is formalized that leads to refuting the statement that A_i is at least as good as A_j, the type of decision problem (choice, scoring, or ranking) they address, the preference model they adopt (whether or not Weber-Fechner's psychophysical law is to be embraced), whether or not the concept of probability is used, and the way criteria weights are determined. A concern has been voiced about how the method combines concordance and discordance that leaves one in doubt about the accuracy of its outcome.

Structuring and Measuring

Bayesian analysis is a popular statistical decision making process which provides a paradigm for updating information in the form of probabilities. It is based on the premise that decisions involving uncertainty can only be made with the aid of information about the uncertain environment in which the decision is made. Bayesian theory updates information by using Bayesian theorem, a statement in conditional probabilities relating causes (states of nature) to outcomes. Outcomes are results of experiments used to uncover the causes. Bayesian theory revises initial or prior probabilities of causes, known from a large sample of a population, into posterior probabilities by using the outcome of an experiment or test with a certain probability of success. Prior probabilities are obtained either subjectively or empirically by sampling the frequency of occurrence of a cause in a population. Posterior probabilities are those based on the prior probabilities and on both the outcome of the experiment and on the

observed reliability of that experiment. Bayesian analysis often makes heavy use of probability trees and that is why we have included them in this section.

Multiattribute Utility (Value) Theory (MAUT/MAVT) [Luce and Suppes, 1964] attempts to maximize a decision maker's utility (under uncertainty) or value (preference) which is represented by a function that maps an object measured on a ratio scale into the decision maker's utility or value relations. The function is constructed by, for example in the case of MAUT, asking lottery questions involving probability to articulate decision makers' value trade-offs among the conflicting attributes. Preferences are used in MAVT. The functional representation of a multicriteria problem is obtained by aggregating the different single attribute functions, each representing a different attribute, by taking into consideration the relative weights of the attributes. The use of objective measurement leads to a complex functional representation if the Weber-Fechner law is to be embraced. The law suggests that the relation between a stimulus and an individual's response is not as smooth as may be indicated by a continuous utility function. Maintaining that "it is now firmly established that expected utility (EU) theory and subjective expected utility (SEU) theory are descriptively invalid," Miyamoto [1992] proposes a generic utility theory, designed as a general framework for descriptive multiattribute utility modeling. A group utility or value function that takes the diversified evaluations of its individual members into consideration, can be obtained either by aggregating individual functions or by partial identification of the group function [Seo, 1985]. Recent versions of MAUT/MAVT have tended to look at the broad complexity of a problem within a structured framework and not simply as criteria and alternatives.

The Analytic Hierarchy Process (AHP) and its generalization to dependence and feedback, the Analytic Network Process (ANP) (Saaty 1990, 2001) use both paired comparisons and ratings to prioritize or rate alternatives one by one on a set of criteria arranged in a hierarchic or in a network structure in the process of developing measurements for intangibles. Tangibles are dealt with directly by using their measurements or indirectly through preference. Priorities are obtained as the principal right eigenvector of a paired comparison reciprocal matrix whose entries belong to a fundamental scale used to express the dominance of each member of a "homogeneous" pair over the other with respect to a common property or criterion. The priorities with respect to each criterion are weighted by the priority of their parent criterion and appropriately summed to obtain the overall priority of each alternative. In more recent extensions of the subject [Saaty 2001] has used benefits, opportunities, costs and risks to analyze decisions and then combine the outcome for the overall outcome for the alternatives. In the AHP/ANP rank preservation and reversal (subjects of considerable debate in the literature early in the history of the method) are allowed to take place depending on whether the alternatives are assumed to be independent both functionally and structurally or not. Paired comparisons always imply structural dependence among the alternatives according to quality and number present. By using the ratings mode or by creating an ideal and

preserving that ideal in making comparisons after the initial set of alternatives, the AHP/ANP always preserves rank when it is assumed that the criteria are independent from the alternatives and alternatives are independent among themselves. The ANP measures and combines the outcome of influence with respect to various criteria: economic, social, political and the like known as control criteria and combines the outcomes for the alternatives by prioritizing the importance of these criteria. Saaty (2003) has generalized AHP/ANP to capture dynamic judgments both mathematically and by using scenarios to project ahead.

4. EVALUATION OF THE METHODS ON THE CRITERIA

Comparison of the group decision-making methods is presented in Table 1.

Group maintenance: leadership effectiveness

Analogy/association, brainstorming, morphological connection, voting, goal programming, and conjoint analysis are rated low because the methods are highly technical. Boundary examination, why-what's stopping, NGT, Delphi, disjointed incrementalism, matrix evaluation, outranking, Bayesian analysis and MAUT/MAVT are rated medium because they provide nothing more than simple structures to assist a facilitator. AHP is rated high because it provides collaborative tools to enhance communication effectiveness, inconsistency and incompatibility measures that provide feedback to the group members to ensure validity of the outcome, structure to facilitate task division, and the means to balance consensus and voting to obtain group judgments.

Group maintenance: learning

Brainstorming, voting, goal programming, and conjoint analysis are rated low because they involve highly technical knowledge. Brainstorming excludes member interaction because of its requirement that there be no discussion or criticism of ideas proposed. Analogy/association, boundary examination, morphological connection, why-what's stopping, NGT, Delphi, and matrix evaluation are rated medium because they improve understanding of the problem, but actions to take from them may not be readily clear. Disjointed incrementalism, outranking, Bayesian analysis and MAUT/MAVT are rated high because it is assumed that their outcomes provide learning that leads to action. Research indicates, however, that despite group satisfaction, study participants rated the combination of NGT and MAUT as low in improving knowledge about the content of the issue [Thomas, McDaniel, and Dooris; 1989]. AHP is rated very high because it provides a highly summarized description of the problem that facilitates learning beyond membership of the group. Participants in an experimental study ranked the AHP as the least difficult and the most trustworthy method among those studied [Schoemaker and Waid, 1982]. It is assumed that the easier to apply and the more trustworthy a method is, the more one learns from its application.

Problem Abstraction: Scope

Voting is rated NA because a group does not generally generate alternatives, and thus broaden the scope, but is somehow given a set of alternatives. Brainstorming does not involve a specific technique to enhance problem abstraction and does not involve problem analysis, and so it is rated low. The use of key words from the original formulation of a problem in analogy and attribute association, which ensures some relations between the analogy or association problem with the original problem, at the same time sets perceptual boundaries. For example, an analogy to a difficulty is usually another difficulty (as opposed to an opportunity) and a spatial problem is likely to generate attributes that direct thinking to increasing the productivity of the space given the same demand, rather than reducing the demand itself. For this reason, these methods are ranked medium. Nominal Group Technique and Delphi are also rated medium because they include careful preparation of a questionnaire for the group to respond to which implies the development of problem abstraction. Disjointed incrementalism, matrix evaluation, goal programming, conjoint analysis, outranking, Bayesian analysis and MAUT/MAVT, and AHP/ANP do not involve a technique to broaden problem abstraction, but since analysis enhances problem abstraction, they are rated medium. Also outranking, Bayesian analysis, MAUT/MAVT, and AHP/ANP are rated medium because they are assumed to apply techniques such as NGT or Delphi that are rated medium. Morphological analysis is rated high because of its systematic search for combinations of attributes that produce candidates for alternatives. Why-what's stopping is also rated high because its why's questions uncover the assumptions underlying the difficulties in implementing the suggested solutions identified by the what's (how's) questions. Structuring the responses to the repeated questions provides highly comprehensive relationships among problems, subproblems, and alternative courses of action. Boundary examination systematically challenges the underlying assumptions regarding the problem, hence it is also rated high.

Table 1. Comparison of Group Decision Making Methods

Method	Group Maintenance		Problem Abstraction		Structure		Analysis	
	Leadership Effectiveness	Learning	Scope	Development of Alternatives	Breadth	Depth	Faithfulness of Judgments	Breadth and Depth of Analysis (What if)
structuring								
Analogy, Association	Low	Medium	Medium	Low	NA	NA	NA	NA
Boundary Examination	Medium	Medium	High	Low	NA	NA	NA	NA
Brainstorming/Brainwriting	Low	Low	Low	Medium	NA	NA	NA	NA
Morphological Connection	Low	Medium	High	Very High	NA	NA	NA	NA
Why-What's Stopping	Medium	Medium	High	Very High	High	High	NA	NA
Ordering and Ranking								
Voting	Low	Low	NA	NA	Low	Low	Low	Low
Nominal Group Technique	Medium	Medium	Medium	High	Low	Low	Low	Low
Delphi	Medium	Medium	Medium	High	Low	Low	Low	Low
Disjointed Incrementalism	Medium	High	Medium	Medium	High	Low	Medium	Medium
Matrix Evaluation	Medium	Medium	Medium	Low	High	Low	Medium	Medium
Goal Programming	Low	Low	Medium	Low	High	Low	Very High	Medium
Conjoint Analysis	Low	Low	Medium	Low	Low	Low	Very High	Medium
Outranking	Medium	High	Medium	High	High	Low	Medium	High
Structuring and Measuring								
Bayesian Analysis	Medium	High	Medium	Low	Low	Low	Very High	Medium
MAUT/MAVT	Medium	High	Medium	High	High	Low	High	High
AHP	High	Very High	Medium	Very High	High	High	Very High	Very High
ANP	High	Very High	Medium	Very High	High	Very High	Very High	Very High

NA = Not Applicable

Table 1. Comparison of Group Decision Making Methods

(cont'd)

Method	Fairness			Applicability, Validity, and Truthfulness				
	Cardinal Separation of Alternatives	Prioritizing Group Members	Consideration of Other Actors and Stakeholders	Scientific and Mathematical Geneality	Applicability to Intangibles	Psychophysical Applicability	Applicability to Conflicy Resolution	Validity of the Outcome (Prediction)
Structuring								
Analogy/Association	NA	NA	NA	NA	NA	NA	NA	NA
Boundary Examination	NA	NA	NA	NA	NA	NA	NA	NA
Brainstorming/Brainwriting	NA	NA	NA	NA	NA	NA	NA	NA
Morphological Connection	NA	NA	NA	NA	NA	NA	NA	NA
Why-What's Stopping	NA	NA	NA	NA	NA	NA	NA	NA
Ordering and Ranking								
Voting	Low	Low	NA	Medium	NA	NA	NA	Low
Nominal Group Technique	NA	NA	NA	Medium	NA	NA	NA	Low
Delphi	NA	NA	NA	Medium	NA	NA	NA	Low
Disjointed Incrementalism	NA	NA	Medium	Low	Low	Low	NA	Medium
Matrix Evaluation	NA	NA	Medium	Low	Low	Low	NA	Medium
Goal Programming	High	NA	Low	Medium	Medium	NA	NA	Low
Conjoint Analysis	High	NA	NA	Medium	Medium	NA	NA	Low
Outranking	High	High	Low	Medium	Medium	Medium	NA	Medium
Structuring and Measuring								
Bayesian Analysis	High	NA	Low	High	Medium	Low	NA	Medium
MAUT/MAVT	High	High	Medium	High	Medium	Medium	Medium	Medium
AHP	High	Very High	High	High	Very High	Very High	High	High
ANP	Very High	Very High	High	High	Very High	Very High	High	High

NA = Not Applicable

Problem abstraction: development of alternatives

Analogy and attribute association, boundary examination, matrix evaluation, goal programming, conjoint analysis and Bayesian analysis are rated low because identifying alternatives is not an explicit part of the method. Brainstorming/brainwriting is rated medium because it ensures a free-wheeling environment but does nothing to take advantage of the positive aspects of interaction among group members. This method assumes that an alternative ranked high by the group is the most relevant solution to the problem, which may not be generally true because the group does not get to bring out possible disadvantages to the suggested alternatives. This weakness is inherent in brainstorming as well as in its modifications, e.g., brainwriting (generating ideas in writing), bug list and negative brainstorming (generating complaints to identify weaknesses). Crawford's blue slip method (independently brainstorming in response to a number of questions that are related to a problem) does not tell one how to organize the information. Brainstorming addresses the negative aspect of communication by removing interaction from the decision process, at the cost of taking advantage of its positive aspects. This may be the reason why this popular method is observed as the least effective technique [Couger, 1995]. Disjointed incrementalism is also rated medium, but because it generates incremental alternatives rather than distinct ones. Nominal Group Technique (NGT) and Delphi are rated high because a certain degree of alignment of group member's perceptions takes place. Outranking and MAUT/MAVT are also rated high, the same as NGT and Delphi, because the complexity of the problem approached using these methods is assumed to require an application of either one of the two alternative generating methods. Morphological connection is mostly useful for new product or new system development, and is rated very high under development of alternatives. Why-what's stopping is also rated very high because the outcome of this method is a highly comprehensive view of the problem and its subproblems, with alternative courses of action included. One potential problem may be that presenting such a broad and detailed analysis may be quite a challenge. AHP is rated very high because, although it may begin with brainstorming as to what alternatives should be located at the bottom of the hierarchy, the level of problem abstraction represented by its hierarchy of criteria provides the opportunity to question whether or not the alternatives that are known indicate appropriate breadth for that level of abstraction.

Structure: breadth

This indicator does not apply to analogy/association, boundary examination, brainstorming/brainwriting, and morphological connection, voting, conjoint analysis and Bayesian analysis. NGT and Delphi are rated low because they are direct comparison methods. Why-what's stopping, disjointed incrementalism, matrix evaluation, outranking, MAUT/MAVT, and AHP are rated high because they do not limit the number of criteria or factors considered in the analysis.

Structure: depth

This indicator does not apply to analogy/association, boundary examination, brainstorming/brainwriting, morphological connection, voting, conjoint analysis and Bayesian analysis. NGT and Delphi are rated low because they are direct comparison methods. Lack of measurement and of theoretical foundation for disjointed incrementalism and matrix evaluation prevent them from constructing a deep structure, hence they are rated low. Goal programming, outranking, and older MAUT are rated low because they have no provision for subcriteria. Why-what's stopping and AHP are rated high because they do not limit the level of detail of the analysis with respect to breaking down criteria into subcriteria, sub-subcriteria and so on.

Analysis: faithfulness of judgments

This indicator, and all others here, do not apply to analogy/association, boundary examination, brainstorming/brainwriting, morphological connection, and why-what's stopping. NGT and Delphi include a voting process to determine which alternative is preferred by the majority of the group members. However, there is an opportunity to use them together with a ratio or an absolute scale evaluation method like the AHP. Voting is rated low because it uses an ordinal scale. Disjointed incrementalism, matrix evaluation, and outranking are rated medium because they involve assigning numbers which can be assumed to represent intensity of importance better than the ordinal rating of voting, for example. MAUT/MAVT is rated high because intensity of preference is derived from lottery judgments which are once removed from direct elicitation of preferences, and AHP is rated very high because it elicits elementary judgments.

Breadth and depth of analysis (analysis)

Voting is rated low because it involves judgment, but not analysis. Disjointed incrementalism, matrix evaluation, goal programming, conjoint analysis and Bayesian analysis are rated medium because they are structurally constrained. MAUT/MAVT is rated high because they provide more structural flexibility but it is difficult to go back and review previous analysis. The AHP is rated very high because its structural flexibility facilitates in-depth analysis of a problem. It also provides inconsistency and incompatibility measures to indicate if some improvement in judgments, and some effort to align perceptions among group members are required. Its supporting software provides the information as to where the sources of inconsistency and incompatibility are.

Fairness: cardinal separation of alternatives

This indicator is applicable only to voting, outranking, MAUT/MAVT, and AHP. Voting is rated low because it uses an ordinal scale, and the others are rated high because they use cardinal scales. ANP is rated very high because feedback improves accuracy of the outcome. Arrow's theorem indicates that any ordinal preference relation, be it expressed as a set of pairwise comparisons or point allocations, does not treat the alternatives fairly.

Fairness: prioritizing group members

This indicator is also applicable only to voting, outranking, MAUT/MAVT, and AHP/ANP. Voting is rated low because fairness is operationalized using head counting with no regard to intensity of preference, which has been argued as unsatisfactory [Dummett, 1984]. Outranking and MAUT/MAVT treat individual members of the group equally. They may in fact, implicitly give them unequal weights, as for example, by giving the boss's opinion greater accord than that of other members of the group in constructing their measures, but the lack of method requires that the relative weights can only be assigned rather arbitrarily. Hence they are rated high. With the AHP/ANP, it is at the decision-maker's discretion to determine what concept of fairness is appropriate, and hence, they are rated very high. A hierarchy can be structured, with the different individuals at the bottom of the hierarchy. The criteria levels may include area of responsibilities or expertise that can be used to prioritize the individuals.

Fairness: consideration of other actors and stakeholders

This indicator is not applicable to analogy/association, boundary examination, brainstorming/brainwriting and morphological connection because they do not involve problem analysis. It is unlikely that this indicator would be applicable to Bayesian analysis because of its complex cause-effect relationship with the states of nature, hence it is rated low. Conjoint analysis is rated low because it may be possible for a creative user to represent other actor's concerns in its model. NGT and Delphi are rated low because they do not make explicit this concern, which might be made implicit by individual members of the group. Matrix evaluation is rated low because of its highly constrained structural representation and non-quantifiable analysis. Outranking is rated low because it obtains a decision with incomplete information, and its theoretical foundation is not yet settled even for the most fundamental issues, making it unlikely that this concern would be addressed and settled once and for all. MAUT/MAVT is rated low because, although it may incorporate this concern as one of its criteria, its limited structural representation makes it difficult to address the possible diversity of actors. Why-what's stopping and disjointed incrementalism may address the issue explicitly, but qualitatively, and are rated medium. It appears that the AHP is the only method that facilitates for a group to explicitly include other actor's concerns in detail as parts of the problem structure, and quantify them, hence it is rated high.

Scientific and mathematical generality

This indicator is not applied to analogy/association, boundary examination, brainstorming/brainwriting, morphological connection, why-what's stopping, NGT, Delphi, because they do not involve problem analysis. Disjointed incrementalism and matrix evaluation are rated low because they do not involve mathematics. Voting is rated medium because there are many procedures proposed for aggregating ordinal votes, with or without axiomatization. The ones that are axiomatized are usually mathematically complex to deal with the

impossibility inherent in ordinal group aggregation. Goal programming and conjoint analysis are rated medium because they do not involve axiomatization. Outranking is rated medium because it is not yet axiomatized. Bayesian Analysis, and MAUT/MAVT are rated high because they are axiomatically solid but their generalization's have considerable mathematical difficulties. The AHP is rated very high because its mathematical foundation is generalizable without additional assumptions.

Applicability to intangibles

This indicator is not applied to analogy/association, boundary examination, brainstorming/brainwriting, morphological connection, why-what's stopping, NGT, Delphi and voting because they do not involve problem analysis. Disjointed incrementalism and matrix evaluation are qualitative methods and are rated low. Goal programming and conjoint analysis may incorporate intangibles in their model, but they must be represented by tangibles with absolute measurement, hence they are rated medium. Outranking and MAUT/MAVT are rated medium because they must use absolute measurement. Medium is probably a generous judgment because MAUT is riddled with unresolved paradoxes and problems and "the standard theory is being challenged on several grounds from both within and outside economics [Machina, 1987]." Bayesian analysis deals with the probability of events, and is rated medium because it often contrives and guesses at its prior probabilities without adequate scientific justification. AHP is rated very high because its fundamental measurement ensures its applicability to intangibles naturally, that gives discretion to the user whether to use relative, ideal or absolute measurement [Saaty, 1990].

Psychophysical applicability

Psychophysical applicability does not apply to voting, goal programming and conjoint analysis. Disjointed incrementalism, matrix evaluation and Bayesian analysis are rated low because psychophysical law is irrelevant. Outranking and MAUT/MAVT are rated medium because they generally do not incorporate the psychophysical phenomenon. If they do, it would complicate the mathematical representation of the theory considerably. AHP is rated high because in many examples, its priority scales approach has produced measurement of responses to physical stimuli that corresponded closely to the normalized values of physical measurement of those stimuli in the homogeneous ranges in which they were examined.

Applicability to conflict resolution

There are only two theories applicable to conflict resolution, game theory that is based on the utility theory, and the AHP/ANP. AHP/ANP is rated high because it allows a wide range of structure from a simple one to a set of benefits-opportunities-costs-risks models with feedback for improvements.

Validity of the outcome (what if)

This indicator is not applied to analogy/association, boundary examination, brainstorming/brainwriting, morphological connection, why-what's stopping, NGT and Delphi because they do not involve problem analysis. Voting is rated low because it uses ordinal measurement with no problem representation, Disjointed incrementalism and matrix evaluation are rated medium because they are limited in terms of measurement and model representation, Goal programming, conjoint analysis, and Bayesian analysis are rated medium because their main concern is with computation, not with problem representation. Outranking and MAUT/MAVT are rated medium because they use cardinal measurement with a relatively simplified model representation. AHP is rated high because its reliance on absolute scales derived from paired comparisons, enabling one to model a problem by ordering its elements and levels in a fine, structured way to legitimize the meaningfulness of the comparisons, and also because different ratio scales can be multiplied and divided to obtain an outcome from hierarchies of benefits, costs, risks, and opportunities.

Research indicates that sometimes a method does not perform as intended. For example, instead of directing decision makers to profitable investment, a series of experiments indicate that the use of the Boston Consulting Group (BCG) matrix increases the subject's likelihood of selecting less profitable investment [Armstrong and Brodie, 1994] due to misuse of the method [Wensley, 1994].

5. CONCLUSION

This paper has brought many criteria and many methods under one umbrella. We believe that our schematization is a good start and may eventually be improved upon in subsequent revisions and extensions of the criteria used and in debating the importance of these criteria and the accuracy with which they are used to evaluate the methods of MCDM.

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