The Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) for Decision Making

Decision Making involves setting priorities and the AHP/ANP is the methodology for doing that.
The book MEASUREMENTS, NUMBERS, AND SIZES ENCOUNTERED IN EVERYDAY LIFE (Viking Penguin, 1989) by Mary Blocksma acclaimed at the time by Scientific American as one of the best science books of the year, lists slightly over 100 variables for which there is some kind of measurement, and only a few of these are legitimate for strictly mathematical representation.
In his book *The Process of Cognition*, Prentice Hall, 1977, Arthur Blumenthal (Blumenthal 1977) writes that there are two types of judgment:

*Comparative judgment* which is the identification of some relation between two stimuli both present to the observer, and *absolute judgment* which involves the relation between a single stimulus and some information held in short term memory about some former comparison stimuli or about some previously experienced measurement scale using which the observer rates the single stimulus.

Henri Lebesgue, who was concerned with questions of measure theory and measurement, wrote in his book *Lecons sur l’intégration*, 2nd ed., Gauthier-Villars, (1928) Paris:

"It would seem that the principle of economy would always require that we evaluate ratios directly and not as ratios of measurements. However, in practice, all lengths are measured in meters, all angles in degrees, etc.; that is we employ auxiliary units and, as it seems, with only the disadvantage of having two measurements to make instead of one. Sometimes, this is because of experimental difficulties or impossibilities that prevent the direct comparison of lengths or angles. But there is also another reason. In geometrical problems, one needs to compare two lengths, for example, and only those two. It is quite different in practice when one encounters a hundred lengths and may expect to have to compare these lengths two at a time in all possible manners. Thus it is desirable and economical procedure to measure each new length. One single measurement for each length, made as precisely as possible, gives the ratio of the length in question to each other length. This explains the fact that in practice, comparisons are never, or almost never, made directly, but through comparisons with a standard scale."
For a very long time people believed and argued strongly that it is impossible to express the intensity of people’s feelings with numbers. The epitome of such a belief was expressed by A.F. MacKay who writes in his book MacKay, A.F. Arrow’s Theorem: The Paradox of Social Choice - A Case Study in the Philosophy of Economics. New Haven: Yale University Press, 1980, that pursuing the cardinal approaches is like chasing what cannot be caught. It was also expressed by Davis, P.J. and R. Hersh, “Descartes Dream”, Harcourt Brace and Jovanovich, New York, 1986, “If you are more of a human being, you will be aware there are such things as emotions, beliefs, attitudes, dreams, intentions, jealousy, envy, yearning, regret, longing, anger, compassion and many others. These things- the inner world of human life- can never be mathematized.”

In their book Einstein's space and Van Gogh's sky: Physical reality and beyond, Macmillan, 1982, Lawrence LeShan and Henry Margenau write: We cannot as we have indicated before, quantify the observables in the domain of consciousness. There are no rules of correspondence possible that would enable us to quantify our feelings. We can make statements of the relative intensity of feelings, but we cannot go beyond this. I can say, "I feel angrier at him today than I did yesterday" "We cannot, however, make meaningful statements such as, I feel three and one half times angrier than I did yesterday.” The physicists' schema, so faithfully emulated by generations of psychologists, epistemologists and aestheticians, is probably blocking their progress, defeating possible insights by its prejudicial force. The schema is not false —it is perfectly reasonable—but it is bootless for the study of mental phenomena.

The Nobel Laureate, Henri Bergson in "The Intensity of Psychic States". Chapter 1 in Time and Free Will: An Essay on the Immediate Data of Consciousness, translated by F.L. Pogson, M.A. London: George Allen and Unwin (1910): 1-74, writes: But even the opponents of psychophysics do not see any harm in speaking of one sensation as being more intense than another, of one effort as being greater than another, and in thus setting up differences of quantity between purely internal states. Common sense, moreover, has not the slightest hesitation in giving its verdict on this point ; people say they are more or less warm, or more or less sad, and this distinction of more and less, even when it is carried over to the region of subjective facts and unextended objects, surprises nobody.
Unrestricted Domain: For each state X and Y, based on the social preference ordering, society prefers either state X to Y or Y to X. i.e. society can compare any pair of candidates (completeness).

Unanimity: If everyone in society prefers a to b, then society should prefer a to b.

Non-Dictatorship: Societal preferences cannot be based on the preferences of only one person regardless of the preferences of other agents and of that person.

Transitive Property: If society prefers (based on social rule aggregation of individual preferences) state X to Y and prefers Y to Z then society prefers X to Z.

Independence of Irrelevant Alternatives: If for some X, Y, and Z, X is preferred to Y, then changing the position in the ordering of Z does not affect the relative ordering of X and Y i.e. X is still preferred to Y. In other words, changing the position of Z in the preference ordering should not be allowed to "flip" the social choice between X and Y.

Universality: Any possible individual rankings of alternatives is permissible.
# Pairwise Comparisons

We assess the relative sizes of the apples by forming ratios. The size comparison tree shows the ratios for each apple:

<table>
<thead>
<tr>
<th>Size Comparison</th>
<th>Apple A</th>
<th>Apple B</th>
<th>Apple C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple A</td>
<td>$S_1/S_1$</td>
<td>$S_1/S_2$</td>
<td>$S_1/S_3$</td>
</tr>
<tr>
<td>Apple B</td>
<td>$S_2/S_1$</td>
<td>$S_2/S_2$</td>
<td>$S_2/S_3$</td>
</tr>
<tr>
<td>Apple C</td>
<td>$S_3/S_1$</td>
<td>$S_3/S_2$</td>
<td>$S_3/S_3$</td>
</tr>
</tbody>
</table>
When the judgments are consistent, as they are here, any normalized column gives the priorities.
Consistency (cont.)

- Consistency itself is a necessary condition for a better understanding of relations in the world but it is not sufficient. For example we could judge all three of the apples to be the same size and we would be perfectly consistent, but very wrong.

- We also need to improve our validity by using redundant information.

- It is fortunate that the mind is not programmed to be always consistent. Otherwise, it could not integrate new information by changing old relations.
## Pairwise Comparisons using Judgments and the Derived Priorities

<table>
<thead>
<tr>
<th>Politician comparisons</th>
<th>B. Clinton</th>
<th>M. Tatcher</th>
<th>G. Bush</th>
<th>Normalized</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B. Clinton</strong></td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>0.6220</td>
<td>1</td>
</tr>
<tr>
<td><strong>M. Tatcher</strong></td>
<td>1/3</td>
<td>1</td>
<td>5</td>
<td>0.2673</td>
<td>0.4297</td>
</tr>
<tr>
<td><strong>G. Bush</strong></td>
<td>1/7</td>
<td>1/5</td>
<td>1</td>
<td>0.1107</td>
<td>0.1780</td>
</tr>
</tbody>
</table>
Scales (From Weakest to Strongest)

- **Nominal Scale** invariant under one to one correspondence where a number is assigned to each object; for example, handing out numbers for order of service to people in a queue.

- **Ordinal Scale** invariant under monotone transformations, where things are ordered by number but the magnitudes of the numbers only serve to designate order, increasing or decreasing; for example, assigning two numbers 1 and 2, to two people to indicate that one is taller than the other, without including any information about their actual heights. The smaller number may be assigned to the taller person and vice versa.

- **Interval Scale** invariant under a positive linear transformation; for example, the linear transformation $F = (9/5) C + 32$ for converting a Celsius to a Fahrenheit temperature reading. Note that one cannot add two readings and on an interval scale because then which is of the form and not of the form. However, one can take an average of such readings because dividing by 2 yields the correct form.

- **Ratio Scale** invariant under a similarity transformation; an example is converting weight measured in pounds to kilograms by using the similarity transformation $K = 2.2 P$. The ratio of the weights of the two objects is the same regardless of whether the measurements are done in pounds or in kilograms. Zero is not the measurement of anything; it applies to objects that do not have the property and in addition one cannot divide by zero to preserve ratios in a meaningful way. Note that one can add two readings from a ratio scale, but not multiply them because does not have the form. The ratio of two readings from a ratio scale such as $6 \text{ kg}/ 3 \text{ kg} = 2$ is a number that belongs to an absolute scale that says that the 6 kg object is twice heavier than the 3 kg object. The ratio 2 cannot be changed by some formula to another number. Thus we introduce the next scale.

- **Absolute Scale**: invariant under the identity transformation $x = x$; for example, numbers used in counting the people in a room.
Clearly in the first formula $n$ is a simple eigenvalue and all other eigenvalues are equal to zero.

A forcing perurbation of eigenvalues theorem:

If $n$ is a simple eigenvalue of $A$, then for small $\epsilon > 0$, there is an eigenvalue $\lambda(\epsilon)$ of $A(\epsilon)$ with power series expansion in $\epsilon$:

$$\lambda(\epsilon) = \lambda + \epsilon \lambda^{(1)} + \epsilon^2 \lambda^{(2)} + \ldots$$

and corresponding right and left eigenvectors $w(\epsilon)$ and $v(\epsilon)$ such that

$$w(\epsilon) = w + \epsilon w^{(1)} + \epsilon^2 w^{(2)} + \ldots$$

$$v(\epsilon) = v + \epsilon v^{(1)} + \epsilon^2 v^{(2)} + \ldots$$
On the Measurement of Inconsistency

A positive reciprocal matrix $A$ has $\lambda_{\text{max}} \geq n$ with equality if and only if $A$ is consistent. As our measure of deviation of $A$ from consistency, we choose the consistency index

$$\mu \equiv \frac{\lambda_{\text{max}} - n}{n - 1}.$$
We obtain the necessary condition on the eigenfunction that it should always satisfy the fundamental functional equation

\[ w(as) = bw(s) \]

where \( b = a \).

This functional equation represents the obvious but powerful fact that response by the brain to a stimulus away from the origin of that stimulus is proportional to response to it at that origin.
It took many months to develop the real and complex solutions of this equation by my friend Janos Aczel, the leading mathematician in the world in the field of functional equations. It has profound implications.

The second term on the right is a periodic function of period one. First we use the solution to derive our 1-9 fundamental scale of judgments. The first order terms in its series expansion is the well known Weber – Fechner law of stimulus response.
The mathematician and cognitive neuropsychologist, Stanislas Dehaene (1997) writes in his book, The Number Sense “Introspection suggests that we can mentally represent the meaning of numbers 1 through 9 with actual acuity. Indeed, these symbols seem equivalent to us. They all seem equally easy to work with, and we feel that we can add or compare any two digits in a small and fixed amount of time like a computer.
The Weber-Fechner Law
We take the ratios of the responses $M_i$ to the first non-zero response $M_1$

$$M_0 = a \log s_0, \ M_1 = a \log \left[ \begin{array} \end{array} \right], \ M_2 = 2a \log \left[ \begin{array} \end{array} \right], \ldots, \ M_n = na \log \left[ \begin{array} \end{array} \right].$$
We know that $\mu \geq 0$ and is zero if and only if $A$ is consistent. Thus the numerator indicates departure from consistency. The term “$n-1$” in the denominator arises as follows: Since trace ($A$) $= n$ is the sum of all the eigenvalues of $A$, if we denote the eigenvalues of $A$ that are different from $\lambda_{\text{max}}$ by $\lambda_2, \ldots, \lambda_{n-1}$, we see that,

$$n = \lambda_{\text{max}} + \sum_{i=2}^{n} \lambda_i$$

so $n - \lambda_{\text{max}} = \sum_{i=2}^{n} \lambda_i$ and $-\mu = \frac{1}{n-1} \sum_{i=2}^{n} \lambda_i$ is the average of the non-principal eigenvalues of $A$.\[\]
The Continuous Case
$K(s,t) \, K(t,s) = 1$

$K(s,t) \, K(t,u)= K(s,u)$, for all $s$, $t$, and $u$
\[ K(s,t) = k_1(s) \cdot k_2(t) \]
\[K(as, at) = aK(s, t) = k(as)/k(at) = a \frac{k(s)}{k(t)}\]
\[ w(as) = bw(s) \]

where \( b = \begin{array}{c} \hat{a} \end{array} \).
\[ v(u) = C_1 e^{-\mu u} P(u) \]

The periodic function is bounded and the negative exponential gives rise to an alternating series. Thus, to a first order approximation this leads to the Weber-Fechner law:
The Weber-Fechner law: Deriving the Scale 1-9
\[ M_0 = a \log s_0, \quad M_1 = a \log \omega, \quad M_2 = 2a \log \omega, \ldots, \quad M_n = na \log \omega. \]

\[ M_i / M_1 = i \]
Verbal Expressions for Making Pairwise Comparison Judgments

- Equal importance
- Moderate importance of one over another
- Strong or essential importance
- Very strong or demonstrated importance
- Extreme importance
Total Dominance

• We have the dominance from the matrix itself by adding its rows and normalizing them. It is a vector each of whose entries is a priority number.

• We have the dominance from the square of the matrix to get dominance in two steps. Similarly for the cube and so on.

• This gives an infinite number of vectors of dominance.

• Their average is the same as we get by raising the matrix to large powers adding its rows and normalizing them.

• This result coincides with the principal eigenvector obtained in the previous way.
Fundamental Scale of Absolute Numbers Corresponding to Verbal Comparisons

1 Equal importance
3 Moderate importance of one over another
5 Strong or essential importance
7 Very strong or demonstrated importance
9 Extreme importance
2, 4, 6, 8 Intermediate values
Use Reciprocals for Inverse Comparisons
### Which Drink is Consumed More in the U.S.?

#### An Example of Estimation Using Judgments

<table>
<thead>
<tr>
<th>Drink Consumption in the U.S.</th>
<th>Coffee</th>
<th>Wine</th>
<th>Tea</th>
<th>Beer</th>
<th>Sodas</th>
<th>Milk</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1/2</td>
</tr>
<tr>
<td>Wine</td>
<td>1/9</td>
<td>1</td>
<td>1/3</td>
<td>1/9</td>
<td>1/9</td>
<td>1/9</td>
<td>1/9</td>
</tr>
<tr>
<td>Tea</td>
<td>1/5</td>
<td>2</td>
<td>1</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
<td>1/9</td>
</tr>
<tr>
<td>Beer</td>
<td>1/2</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>1/2</td>
<td>1</td>
<td>1/3</td>
</tr>
<tr>
<td>Sodas</td>
<td>1</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1/2</td>
</tr>
<tr>
<td>Milk</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>1/2</td>
<td>1</td>
<td>1/3</td>
</tr>
<tr>
<td>Water</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

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
## Estimating which Food has more Protein

<table>
<thead>
<tr>
<th>Food Consumption in the U.S.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Steak</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>B: Potatoes</td>
<td>1</td>
<td>1</td>
<td>1/2</td>
<td>1/4</td>
<td>1/3</td>
<td>1/4</td>
<td></td>
</tr>
<tr>
<td>C: Apples</td>
<td>1</td>
<td>1/3</td>
<td>1/3</td>
<td>1/5</td>
<td>1/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: Soybean</td>
<td>1</td>
<td>1/2</td>
<td>1</td>
<td>1/6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: Whole Wheat Bread</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
<td>1/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F: Tasty Cake</td>
<td>1</td>
<td></td>
<td></td>
<td>1/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G: Fish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

(Reciprocals)

The resulting derived scale and the actual values are shown below:

<table>
<thead>
<tr>
<th></th>
<th>Steak</th>
<th>Potatoes</th>
<th>Apples</th>
<th>Soybean</th>
<th>W. Bread</th>
<th>T. Cake</th>
<th>Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derived</td>
<td>.345</td>
<td>.031</td>
<td>.030</td>
<td>.065</td>
<td>.124</td>
<td>.078</td>
<td>.328</td>
</tr>
<tr>
<td>Actual</td>
<td>.370</td>
<td>.040</td>
<td>.000</td>
<td>.070</td>
<td>.110</td>
<td>.090</td>
<td>.320</td>
</tr>
</tbody>
</table>

(Derived scale has a consistency ratio of .028.)
## WEIGHT COMPARISONS

<table>
<thead>
<tr>
<th>Weight</th>
<th>Radio</th>
<th>Typewriter</th>
<th>Large Attache Case</th>
<th>Projector</th>
<th>Small Attache</th>
<th>Eigenvector</th>
<th>Actual Relative Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>1</td>
<td>1/5</td>
<td>1/3</td>
<td>1/4</td>
<td>4</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Typewriter</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>0.40</td>
<td>0.39</td>
</tr>
<tr>
<td>Large Attache Case</td>
<td>3</td>
<td>1/2</td>
<td>1</td>
<td>1/2</td>
<td>4</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td>Projector</td>
<td>4</td>
<td>1/2</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>0.29</td>
<td>0.27</td>
</tr>
<tr>
<td>Small Attache Case</td>
<td>1/4</td>
<td>1/8</td>
<td>1/4</td>
<td>1/7</td>
<td>1</td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Nonlinearity of the Priorities

**RELATIVE VISUAL BRIGHTNESS-I**

<table>
<thead>
<tr>
<th></th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>C₂</td>
<td>1/5</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>C₃</td>
<td>1/6</td>
<td>1/4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>C₄</td>
<td>1/7</td>
<td>1/6</td>
<td>1/4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>( C_1 )</td>
<td>( C_2 )</td>
<td>( C_3 )</td>
<td>( C_4 )</td>
</tr>
<tr>
<td>-------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>( C_1 )</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>( C_2 )</td>
<td>1/4</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>( C_3 )</td>
<td>1/6</td>
<td>1/3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>( C_4 )</td>
<td>1/7</td>
<td>1/4</td>
<td>1/2</td>
<td>1</td>
</tr>
</tbody>
</table>

**RELATIVE VISUAL BRIGHTNESS -II**
## RELATIVE BRIGHTNESS EIGENVECTOR

### The Inverse Square Law of Optics

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C₁</td>
<td>.62</td>
<td>C₂</td>
<td>.23</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>C₃</td>
<td>.10</td>
<td>C₄</td>
<td>.05</td>
<td>.22</td>
</tr>
<tr>
<td></td>
<td>C₄</td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance</th>
<th>Normalized distance</th>
<th>Square of normalized distance</th>
<th>Reciprocal of previous column</th>
<th>Normalized reciprocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>0.123</td>
<td>0.015</td>
<td>67</td>
<td>0.61</td>
</tr>
<tr>
<td>15</td>
<td>0.205</td>
<td>0.042</td>
<td>24</td>
<td>0.22</td>
</tr>
<tr>
<td>21</td>
<td>0.288</td>
<td>0.083</td>
<td>12</td>
<td>0.11</td>
</tr>
<tr>
<td>28</td>
<td>0.384</td>
<td>0.148</td>
<td>7</td>
<td>0.06</td>
</tr>
</tbody>
</table>
### Relative Electricity Consumption (Kilowatt Hours) of Household Appliances

<table>
<thead>
<tr>
<th>Annual Electric Consumption</th>
<th>Elec. Range</th>
<th>Refrig</th>
<th>TV</th>
<th>Dish Wash</th>
<th>Iron</th>
<th>Radio</th>
<th>Hair Dryer</th>
<th>Eigen-vector</th>
<th>Actual Relative Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Range</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>.393</td>
<td>.392</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>1/2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>.261</td>
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## Relative coin sizes

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<td>Percentage of Individuals that use different search engines</td>
<td>Google</td>
<td>Yahoo</td>
<td>MSN</td>
<td>AOL</td>
<td>My Web</td>
<td>Priorities</td>
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### Relative Distances from Pittsburgh

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<th>L.A.</th>
<th>New Orleans</th>
<th>St. Louis</th>
<th>Washington D.C.</th>
<th>Priorities</th>
<th>Actual Distance In Miles</th>
<th>Relative Values</th>
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<td>BMW - 5</td>
<td>Acura - TL</td>
<td>Lexus - ES</td>
<td>Audi - A6</td>
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<td>Actual Cost</td>
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## Esther Judgments

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<th>Japan</th>
<th>Germany</th>
<th>UK</th>
<th>France</th>
<th>Italy</th>
<th>Canada</th>
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<th>Results</th>
<th>GDP Data</th>
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**SUM**: 0.9998

**Inconsistency**: 0.0334

**Inconsistency Index**: 1.0879
## Gershon Judgments

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<table>
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<td>0.0381</td>
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Inconsistency: 0.0271

*Actual judgment for (UK, France) is inverse: 1/1.2 = 0.833*

Inconsistency Index: 1.0346
# GDP DATA for the Eight Countries

<table>
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<th>Country</th>
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<th>Fraction of Total</th>
<th>Gershon</th>
<th>Esther</th>
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**Compatibility Index**

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<th>$/Person</th>
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<tbody>
<tr>
<td>1US</td>
<td>310,232,863</td>
<td>$45,953</td>
</tr>
<tr>
<td>2Japan</td>
<td>126,804,433</td>
<td>$39,967</td>
</tr>
<tr>
<td>3Germany</td>
<td>82,282,988</td>
<td>$40,737</td>
</tr>
<tr>
<td>4UK</td>
<td>62,348,447</td>
<td>$35,013</td>
</tr>
<tr>
<td>5France</td>
<td>64,768,389</td>
<td>$41,301</td>
</tr>
<tr>
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<td>58,090,681</td>
<td>$36,460</td>
</tr>
<tr>
<td>7Canada</td>
<td>33,759,742</td>
<td>$39,574</td>
</tr>
<tr>
<td>8Russia</td>
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<tr>
<td>Country</td>
<td>Population</td>
<td>$/Person</td>
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<tr>
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<tr>
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<td>139,390,205</td>
<td>$8,817</td>
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Comparing No More Than About Seven Elements

**Table** Random index

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</table>
This means that \(34.14/.07 = 487.7\) unripe cherry tomatoes are equal to the oblong watermelon.
Comparing a Dog-Catcher w/ President

<table>
<thead>
<tr>
<th>Dog Catcher</th>
<th>Traffic Cop</th>
<th>Patrol Cop</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Dog Catcher Image" /></td>
<td><img src="image2" alt="Traffic Cop Image" /></td>
<td><img src="image3" alt="Patrol Cop Image" /></td>
</tr>
<tr>
<td>0.07</td>
<td>0.28</td>
<td>0.65</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Patrol Cop</th>
<th>Detective</th>
<th>Chief of Police</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Patrol Cop Image" /></td>
<td><img src="image5" alt="Detective Image" /></td>
<td><img src="image6" alt="Chief of Police Image" /></td>
</tr>
<tr>
<td>0.08</td>
<td>0.22</td>
<td>0.70</td>
</tr>
<tr>
<td>[ \frac{0.08}{0.08} = 1 ]</td>
<td>[ \frac{0.22}{0.08} = 2.75 ]</td>
<td>[ \frac{0.70}{0.08} = 8.75 ]</td>
</tr>
<tr>
<td>0.65H1 = 0.65</td>
<td>0.65H2.75 = 1.79</td>
<td>0.65H8.75 = 5.69</td>
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</table>

<table>
<thead>
<tr>
<th>Chief of Police</th>
<th>Mayor Council Member</th>
<th>Mayor</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image7" alt="Chief of Police Image" /></td>
<td><img src="image8" alt="Mayor Council Member Image" /></td>
<td><img src="image9" alt="Mayor Image" /></td>
</tr>
<tr>
<td>0.10</td>
<td>0.30</td>
<td>0.60</td>
</tr>
<tr>
<td>[ \frac{0.10}{0.10} = 1 ]</td>
<td>[ \frac{0.30}{0.10} = 3 ]</td>
<td>[ \frac{0.60}{0.10} = 6 ]</td>
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<td>5.69H1 = 5.69</td>
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</table>
Comparing a Dog-Catcher w/ President

Figure 1: Comparisons According to Importance
Goal
Satisfaction with School

- Learning
- Friends
- School Life
- Vocational Training
- College Prep.
- Music Classes

School A
School B
School C
## School Selection

<table>
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<th>F</th>
<th>SL</th>
<th>VT</th>
<th>CP</th>
<th>MC</th>
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<td>1</td>
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Comparison of Schools with Respect to the Six Characteristics

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Composition and Synthesis
Impacts of School on Criteria

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The School Example Revisited Composition & Synthesis: Impacts of Schools on Criteria

### Distributive Mode

(Normalization: Dividing each entry by the total in its column)

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<td>.25</td>
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<td>.25</td>
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</tbody>
</table>

The Distributive mode is useful when the uniqueness of an alternative affects its rank. The number of copies of each alternative also affects the share each receives in allocating a resource. In planning, the scenarios considered must be comprehensive and hence their priorities depend on how many there are. This mode is essential for ranking criteria and sub-criteria, and when there is dependence.

### Ideal Mode

(Dividing each entry by the maximum value in its column)

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<td>.32</td>
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<td>.27</td>
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</table>

The Ideal mode is useful in choosing a best alternative regardless of how many other similar alternatives there are.
A Complete Hierarchy to Level of Objectives

Focus:
At what level should the Dam be kept: Full or Half-Full

Decision Criteria:
- Financial
- Political
- Env’t Protection
- Social Protection

Decision Makers:
- Congress
- Dept. of Interior
- Courts
- State
- Lobbies

Factors:
- Clout
- Legal Position
- Potential Financial Loss
- Irreversibility of the Env’t
- Archeological Problems
- Current Financial Resources

Groups Affected:
- Farmers
- Recreationists
- Power Users
- Environmentalists

Objectives:
- Irrigation
- Flood Control
- Flat Dam
- White Dam
- Cheap Power
- Protect Environment

Alternatives:
- Half-Full Dam
- Full Dam
Evaluating Employees for Raises

GOAL

Dependability
- Outstanding (0.48) \( .48/48 = 1 \)
- Very Good (0.28) \( .28/48 = .58 \)
- Good (0.16) \( .16/48 = .33 \)
- Below Avg. (0.05) \( .05/48 = .10 \)
- Unsatisfactory (0.03) \( .03/48 = .06 \)

Education
- Doctorate (0.59) \( .59/59 = 1 \)
- Masters (0.25) \( .25/59 = .43 \)
- Bachelor (0.11) etc.
- High School (0.05)

Experience
- >15 years (0.61)
- 6-15 years (0.25)
- 3-5 years (0.10)
- 1-2 years (0.04)

Quality
- Excellent (0.64)
- Very Good (0.21)
- Good (0.11)
- Poor (0.04)

Attitude
- Enthused (0.63)
- Above Avg. (0.23)
- Average (0.10)
- Negative (0.04)

Leadership
- Outstanding (0.54)
- Above Avg. (0.23)
- Average (0.14)
- Below Avg. (0.06)
- Unsatisfactory (0.03)
Final Step in Absolute Measurement

Rate each employee for dependability, education, experience, quality of work, attitude toward job, and leadership abilities.

<table>
<thead>
<tr>
<th>Name</th>
<th>Dependability</th>
<th>Education</th>
<th>Experience</th>
<th>Quality</th>
<th>Attitude</th>
<th>Leadership</th>
<th>Total</th>
<th>Normalized</th>
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<td>Doctorate</td>
<td>&gt;15 years</td>
<td>Excellent</td>
<td>Enthused</td>
<td>Outstand</td>
<td>1.000</td>
<td>0.153</td>
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<td>Masters</td>
<td>&gt;15 years</td>
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<td>Enthused</td>
<td>Abv. Avg.</td>
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<td>Masters</td>
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<td>Average</td>
<td>Average</td>
<td>0.641</td>
<td>0.098</td>
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<tr>
<td>Becker, L.</td>
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<td>Excellent</td>
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<td>Average</td>
<td>0.580</td>
<td>0.089</td>
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<tr>
<td>Adams, V.</td>
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<td>3-5 years</td>
<td>Excellent</td>
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<td>Average</td>
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<td>0.086</td>
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<td>3-5 years</td>
<td>Excellent</td>
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<td>Average</td>
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<td>Average</td>
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<td>0.071</td>
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<tr>
<td>Washington, S.</td>
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<td>3-5 years</td>
<td>V. Good</td>
<td>Average</td>
<td>Average</td>
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<td>.15 years</td>
<td>V. Good</td>
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<td>Abv. Avg.</td>
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</table>

The total score is the sum of the weighted scores of the ratings. The money for raises is allocated according to the normalized total score. In practice different jobs need different hierarchies.
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 (IM):** 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 (M):** Ability to use and respond to different openings, improvise middle game tactics, and steer the game to a familiar ground to one's advantage.
Linear Hierarchy

Goal

Criteria

Subcriteria

A loop indicates that each element depends only on itself.
Feedback Network with components having Inner and Outer Dependence among Their Elements

Arc from component $C_4$ to $C_2$ indicates the outer dependence of the elements in $C_2$ on the elements in $C_4$ with respect to a common property.

Loop in a component indicates inner dependence of the elements in that component with respect to a common property.
### Networks and the Supermatrix

\[
W = \begin{bmatrix}
    W_{11} & W_{12} & \cdots & W_{1N} \\
    W_{21} & W_{22} & \cdots & W_{2N} \\
    \vdots & \vdots & \ddots & \vdots \\
    W_{N1} & W_{N2} & \cdots & W_{NN}
\end{bmatrix}
\]

- **C** represents the sets of nodes in the network.
- **e** represents the edges or connections between nodes.
- **W** is the supermatrix that summarizes the interaction between nodes.
where

\[
W_{ij} = \begin{bmatrix}
W_{i1}^{(j_1)} & W_{i1}^{(j_2)} & \cdots & W_{i1}^{(j_{n_j})} \\
W_{i2}^{(j_1)} & W_{i2}^{(j_2)} & \cdots & W_{i2}^{(j_{n_j})} \\
\vdots & \vdots & \ddots & \vdots \\
W_{in_j}^{(j_1)} & W_{in_j}^{(j_2)} & \cdots & W_{in_j}^{(j_{n_j})}
\end{bmatrix}
\]
Supermatrix of a Hierarchy

\[
W = \begin{bmatrix}
C_1 & C_2 & \cdots & \cdots & C_{N-2} & C_{N-1} & C_N \\
C_1 & 0 & \cdots & \cdots & 0 & \cdots & 0 \\
\vdots & \ddots & \cdots & \cdots & \vdots & \cdots & \vdots \\
C_{N-2} & \cdots & \cdots & \cdots & 0 & \cdots & 0 \\
C_{N-1} & \cdots & \cdots & \cdots & \cdots & \ddots & \vdots \\
C_N & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\
e_{NnN} & \cdots & \cdots & \cdots & \cdots & \cdots & e_{nNnN}
\end{bmatrix}
\]
$W^k =$

$$
\begin{bmatrix}
0 & 0 & \cdots & 0 \\
0 & 0 & \cdots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \cdots & 0 \\
W_{n,n-1} & W_{n-1,n-2} & \cdots & W_{32} & W_{21} & W_{n,n-1} & W_{n-1,n-2} & \cdots & W_{32} & \cdots & W_{n,n-1} & W_{n-1,n-2} & W_{n,n-1} & I
\end{bmatrix}
$$

for $k > n-1$
### The School Hierarchy as Supermatrix

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<th>Goal</th>
<th>Learning</th>
<th>Friends</th>
<th>School life</th>
<th>Vocational training</th>
<th>College preparation</th>
<th>Music classes</th>
<th>A</th>
<th>B</th>
<th>C</th>
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### Limiting Supermatrix & Hierarchic Composition

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<th>School life</th>
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The U.S. Holarchy of Factors for Forecasting Turnaround in Economic Stagnation

Primary Factors

Adjustment Period Required for Turnaround

3 months   6 months   12 months   24 months

Subfactors

Date and Strength of Recovery of U.S. Economy

Conventional adjustment

Economic Restructuring

Consumption (C)
Exports (X)
Investment (I)
Fiscal Policy (F)
Monetary Policy (M)
Confidence (K)

Financial Sector (FS)
Defense Posture (DP)
Global Competition (GC)
### Panel A: Which subfactor has the greater potential to influence Conventional Adjustment and how strongly?

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<th>K</th>
<th>F</th>
<th>M</th>
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### Panel B: Which subfactor has the greater potential to influence Economic Restructuring and how strongly?

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<td>6 months &amp; 1 &amp; 1 &amp; 1/5 &amp; 1/5</td>
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<td>12 months &amp; 5 &amp; 5 &amp; 1 &amp; 1</td>
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<td>6 months &amp; 1 &amp; 1 &amp; 1/5 &amp; 1/5</td>
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<td>12 months &amp; 5 &amp; 5 &amp; 1 &amp; 1/3</td>
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<td>6 months &amp; 1 &amp; 1 &amp; 1/5 &amp; 1/5</td>
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<tr>
<td>12 months &amp; 3 &amp; 5 &amp; 1 &amp; 1</td>
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<th>Panel E: Relative importance of targeted time periods for monetary policy to drive a turnaround</th>
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<td>6 months &amp; 1/5 &amp; 1 &amp; 5 &amp; 7</td>
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<tr>
<th>Panel F: Expected time for a change of confidence indicators of consumer and investor activity to support a turnaround in the economy</th>
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<td>6 months &amp; 1/3 &amp; 1 &amp; 5 &amp; 5</td>
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<td>12 months &amp; 1/5 &amp; 1/5 &amp; 1 &amp; 1</td>
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<td>24 months &amp; 1/5 &amp; 1/5 &amp; 1/5 &amp; 1</td>
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**Table 3: Matrices for relative influence of subfactors on periods of adjustment (months)**

*(Economic Restructuring)*

For each panel below, which time period is more likely to indicate a turnaround if the relevant factor is the sole driving force?

<table>
<thead>
<tr>
<th>Panel A: Financial system restructuring time</th>
<th>Panel B: Defense readjustment time</th>
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<td>6 months</td>
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<td>12 months</td>
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<td>24 months</td>
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<table>
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<th>Panel C: Global competition adjustment time</th>
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<td>12 months</td>
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<tr>
<td>24 months</td>
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**Table 4: Most likely factor to dominate during a specified time period**

Which factor is more likely to produce a turnaround during the specified time period?

Conventional Adjustment  
Restructuring

<table>
<thead>
<tr>
<th>Panel A: 3 Months</th>
<th>Panel B: 6 Months</th>
<th>Panel C: 1 Year</th>
<th>Panel D: 2 Years</th>
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<tr>
<td>R</td>
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<td>.167</td>
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### Table 5: The Completed Supermatrix

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### Table 6: The Limiting Supermatrix

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</table>

**3 months**: 0.224, 0.224

**6 months**: 0.151, 0.151

**1 year**: 0.201, 0.201

**≥ 2 years**: 0.424, 0.424
Synthesis/ Results

When the judgments were made, the AHP framework was used to perform a synthesis that produced the following results. First a meaningful turnaround in the economy would likely require an additional ten to eleven months, occurring during the fourth quarter of 1992. This forecast is derived from weights generated in the first column of the limiting matrix in Table 6, coupled with the mid-points of the alternate time periods (so as to provide unbiased estimates:

\[
.224 \times 1.5 + .151 \times 4.5 + .201 \times 9 + .424 \times 18 = 10.45 \text{ months from late December 1991/early January 1992}
\]
Two Important Observations

For Costs and Risks we Must Ask,
Which is More Costly and Which is More Risky

We Must Also compare the Clusters Themselves as to Their Influence on Each Other Cluster in Order to Render the Super Matrix Stochastic. We do it in Several Separate Matrices of Paired Comparisons
## Airlines’ Market Shares

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<thead>
<tr>
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<th>Actual (yr 2000)</th>
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<td>18.0</td>
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<td>Northwest</td>
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<td>12.4</td>
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<tr>
<td>Continental</td>
<td>9.3</td>
<td>10.0</td>
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<td>US Airways</td>
<td>7.5</td>
<td>7.1</td>
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<tr>
<td>Southwest</td>
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</tr>
<tr>
<td>American West</td>
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</table>
Amit Prashar (February, 2005 class) upon seeing his market share results wrote:

<table>
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<th>Super Decision Output</th>
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<tr>
<td>Dell</td>
<td>64.75%</td>
<td>67.83%</td>
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<tr>
<td>IBM</td>
<td>22.60%</td>
<td>23.56%</td>
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<tr>
<td>Toshiba</td>
<td>12.64%</td>
<td>8.61%</td>
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</table>

Saaty Compatibility Index 1.041 which is much less than 1.10 recommended

The results are very close (I WAS REALLY STUNNED.....Geez..- UNBELIEVABLE)
National Missile Defense (NMD)

Prioritization of national US criteria

Strategic Criteria for Evaluating Merits

- World Peace: 0.648
  - Adversary Countries: 0.237
  - Security Dilemma: 0.449
  - Terrorism: 0.314

- Human Well-being: 0.122
  - Technological Advancement: 0.667
  - Market Creation: 0.333

- International Politics: 0.230
  - Military Relations: 0.600
  - Diplomatic Relations: 0.400
## Criteria and Their Priorities

<table>
<thead>
<tr>
<th>Merits</th>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>Global Priorities (Normalized)</th>
</tr>
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<td>Benefits</td>
<td>Economic (0.157)</td>
<td>Local Economy (0.141)</td>
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</table>
Decision Network under Military Capability Control Subcriterion of Benefits
National Missile Defense (NMD)

Prioritization of national US criteria

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<td>0.170b</td>
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Pairwise comparing components with respect to the Congress component
Q: Which of a pair of components is influenced more by the Congress component with respect to Military Capability?

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<th>Pres~</th>
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Pairwise comparing components with respect to the Foreign Countries component
Q: Which of a pair of components is influenced more by the Foreign Countries component with respect to Military Capability?

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<th>Pres~</th>
<th>Prior.</th>
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<td>0.2204</td>
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Pairwise comparing components with respect to the Technical Experts component
Q: Which of a pair of components is influenced more by the Technical Experts component with respect to Military Capability?

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<th>Pres~</th>
<th>Prior.</th>
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<tbody>
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<td>3.0682</td>
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<td>0.5548</td>
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Pairwise comparing components with respect to the Defense Industry component
Q: Which of a pair of components is influenced more by the Defense Industry component with respect to Military Capability?

<table>
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<th>Cong~</th>
<th>Pres~</th>
<th>Prior.</th>
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<td>1.5152</td>
<td>1.0000</td>
<td>0.4528</td>
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</table>

Pairwise comparing components with respect to the President/Military component
Q: Which of a pair of components is influenced more by the President/Military component with respect to Military Capability?

<table>
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<tr>
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<th>Cong~</th>
<th>For~</th>
<th>Prior.</th>
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Priorities Matrix of Eigenvectors
How much components are influenced by each component; imported from the matrices of the table above

<table>
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<tr>
<th>Clusters</th>
<th>Altern~</th>
<th>Cong~</th>
<th>Def. Ind~</th>
<th>For~</th>
<th>Pres~</th>
<th>Tech~</th>
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</thead>
<tbody>
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<tr>
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</table>

The Weighted Supermatrix
Priorities from the above table are used to weight the corresponding blocks of the unweighted supermatrix

<table>
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<tr>
<th>MiCap</th>
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<th>Cong~</th>
<th>Def. Ind~</th>
<th>For~</th>
<th>Pres~</th>
<th>Tech~</th>
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<tr>
<td>Def. Ind~</td>
<td>0.1737</td>
<td>0.1653</td>
<td>0.1737</td>
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<td>0.1671</td>
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</tr>
<tr>
<td>For~</td>
<td>0.0446</td>
<td>0.0425</td>
<td>0.0446</td>
<td>0.0000</td>
<td>0.0784</td>
<td>0.0784</td>
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<tr>
<td>Pres/Mil~</td>
<td>0.3933</td>
<td>0.3742</td>
<td>0.3933</td>
<td>0.0000</td>
<td>0.0313</td>
<td>0.0313</td>
</tr>
<tr>
<td>Tech~</td>
<td>0.0846</td>
<td>0.0805</td>
<td>0.0846</td>
<td>0.0000</td>
<td>0.1191</td>
<td>0.1191</td>
</tr>
</tbody>
</table>

The Limit Supermatrix
The weighted supermatrix raised to sufficiently large powers to stabilize within rounded off four place decimals

<table>
<thead>
<tr>
<th>MiCap</th>
<th>Altern~</th>
<th>Cong~</th>
<th>Def. Ind~</th>
<th>For~</th>
<th>Pres/Mil~</th>
<th>Tech~</th>
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<tbody>
<tr>
<td>NMD</td>
<td>0.1532</td>
<td>0.1532</td>
<td>0.1532</td>
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<td>Glob~</td>
<td>0.0968</td>
<td>0.0968</td>
<td>0.0968</td>
<td>0.0000</td>
<td>0.0968</td>
<td>0.0968</td>
</tr>
<tr>
<td>R &amp; D</td>
<td>0.0438</td>
<td>0.0438</td>
<td>0.0438</td>
<td>0.0000</td>
<td>0.0438</td>
<td>0.0438</td>
</tr>
<tr>
<td>Term~</td>
<td>0.0201</td>
<td>0.0201</td>
<td>0.0201</td>
<td>0.0000</td>
<td>0.0201</td>
<td>0.0201</td>
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<tr>
<td>Cong~</td>
<td>0.2224</td>
<td>0.2224</td>
<td>0.2224</td>
<td>0.0000</td>
<td>0.2224</td>
<td>0.2224</td>
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<tr>
<td>Def. Ind~</td>
<td>0.0513</td>
<td>0.0513</td>
<td>0.0513</td>
<td>0.0000</td>
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</tr>
<tr>
<td>For~</td>
<td>0.0619</td>
<td>0.0619</td>
<td>0.0619</td>
<td>0.0000</td>
<td>0.0619</td>
<td>0.0619</td>
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<tr>
<td>Pres/Mil~</td>
<td>0.3255</td>
<td>0.3255</td>
<td>0.3255</td>
<td>0.0000</td>
<td>0.3255</td>
<td>0.3255</td>
</tr>
<tr>
<td>Tech~</td>
<td>0.0250</td>
<td>0.0250</td>
<td>0.0250</td>
<td>0.0000</td>
<td>0.0250</td>
<td>0.0250</td>
</tr>
</tbody>
</table>
# IDEALIZED DECISION NETWORK VECTORS times NORMALIZED CONTROL CRITERIA

## Benefits

<table>
<thead>
<tr>
<th>Control Criterion wt. (CC)</th>
<th>Military Capability</th>
<th>Technical Advancement</th>
<th>SUM of wtd Alts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized CC</td>
<td>0.542</td>
<td>0.458</td>
<td>Col 1 + Col 2</td>
</tr>
<tr>
<td><strong>Alternatives</strong></td>
<td>Idealized (CC x Ideal)</td>
<td>Idealized (CC x Ideal)</td>
<td>SUM</td>
</tr>
<tr>
<td>Deploy</td>
<td>1.000</td>
<td>0.928</td>
<td>0.967</td>
</tr>
<tr>
<td>Global</td>
<td>0.623</td>
<td>1.000</td>
<td>0.796</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.282</td>
<td>0.448</td>
<td>0.358</td>
</tr>
<tr>
<td>Terminate</td>
<td>0.129</td>
<td>0.085</td>
<td>0.109</td>
</tr>
</tbody>
</table>

## Opportunities

<table>
<thead>
<tr>
<th>Control Criteria (CC)</th>
<th>Arms Sales</th>
<th>Spinoff</th>
<th>SUM of wtd Alts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized CC</td>
<td>0.614</td>
<td>0.386</td>
<td>Col 1 + Col 2</td>
</tr>
<tr>
<td><strong>Alternatives</strong></td>
<td>Idealized (CC x Ideal)</td>
<td>Idealized (CC x Ideal)</td>
<td>SUM</td>
</tr>
<tr>
<td>Deploy</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Global</td>
<td>0.674</td>
<td>0.521</td>
<td>0.614</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.341</td>
<td>0.288</td>
<td>0.321</td>
</tr>
<tr>
<td>Terminate</td>
<td>0.190</td>
<td>0.166</td>
<td>0.181</td>
</tr>
</tbody>
</table>

## Costs

<table>
<thead>
<tr>
<th>Control Criteria (CC)</th>
<th>Sec. Threat</th>
<th>Sunk Cost</th>
<th>Further Inv.</th>
<th>SUM of Col's 1+2+3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized CC</td>
<td>0.751</td>
<td>0.134</td>
<td>0.115</td>
<td>Col 3</td>
</tr>
<tr>
<td><strong>Alternatives</strong></td>
<td>Idealized (CC x Ideal)</td>
<td>Idealized (CC x Ideal)</td>
<td>Idealized (CC x Ideal)</td>
<td>SUM</td>
</tr>
<tr>
<td>Deploy</td>
<td>0.183</td>
<td>1.000</td>
<td>1.000</td>
<td>0.386</td>
</tr>
<tr>
<td>Global</td>
<td>0.344</td>
<td>0.574</td>
<td>0.496</td>
<td>0.393</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.579</td>
<td>0.332</td>
<td>0.279</td>
<td>0.512</td>
</tr>
<tr>
<td>Terminate</td>
<td>1.000</td>
<td>0.193</td>
<td>0.147</td>
<td>0.794</td>
</tr>
</tbody>
</table>

## Risks

<table>
<thead>
<tr>
<th>Control Criteria (CC)</th>
<th>Tech Failure</th>
<th>Arms Race</th>
<th>SUM of Col's 1 + 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized CC</td>
<td>0.616</td>
<td>0.384</td>
<td></td>
</tr>
<tr>
<td><strong>Alternatives</strong></td>
<td>Idealized (CC x Ideal)</td>
<td>Idealized (CC x Ideal)</td>
<td>SUM</td>
</tr>
<tr>
<td>Deploy</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Global</td>
<td>0.621</td>
<td>0.693</td>
<td>0.648</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.375</td>
<td>0.441</td>
<td>0.401</td>
</tr>
<tr>
<td>Terminate</td>
<td>0.262</td>
<td>0.302</td>
<td>0.277</td>
</tr>
</tbody>
</table>
## Priority Ratings for the Merits: Benefits, Opportunities, Costs and Risks

Very High (0.419), High (0.263), Medium (0.160), Low (0.097), Very Low (0.061)

* Idealized: Very High (1.000), High (0.619), Medium (0.381), Low (0.238), Very Low (0.143)

<table>
<thead>
<tr>
<th>Priority</th>
<th>Threats</th>
<th>Benefits</th>
<th>Opportunities</th>
<th>Costs</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Peace</td>
<td>Adversary Countries</td>
<td>Very High</td>
<td>Medium</td>
<td>High</td>
<td>Very Low</td>
</tr>
<tr>
<td>Security Dilemma</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very High</td>
<td>Very Low</td>
<td></td>
</tr>
<tr>
<td>Terrorism</td>
<td>Medium</td>
<td>Very Low</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Human Well-Being</td>
<td>Technological Advancement</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>Market Creation</td>
<td>Medium</td>
<td>High</td>
<td>Very Low</td>
<td></td>
</tr>
<tr>
<td>International Politics</td>
<td>Military Relations</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>Diplomatic Relations</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Very High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Ratings</th>
<th>Benefits</th>
<th>Opportunities</th>
<th>Costs</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.446</td>
<td>0.380</td>
<td>0.611</td>
<td>0.318</td>
<td></td>
</tr>
<tr>
<td>Normalized</td>
<td>0.264β</td>
<td>0.184β</td>
<td>0.363β</td>
<td>0.188β</td>
</tr>
</tbody>
</table>
### Sum of the BOCR merit priorities times the “Totals” for their control criteria

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Benefits (Sum from above)</th>
<th>(Sum x .264)</th>
<th>Opportunities (Sum from above)</th>
<th>(Sum x .184)</th>
<th>Costs (Sum from above)</th>
<th>(Sum x .363)</th>
<th>Risks (Sum from above)</th>
<th>(Sum x .188)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deploy</td>
<td>0.967</td>
<td>0.255</td>
<td>1.000</td>
<td>0.184</td>
<td>0.386</td>
<td>0.140</td>
<td>1.000</td>
<td>0.188</td>
</tr>
<tr>
<td>Global</td>
<td>0.796</td>
<td>0.210</td>
<td>0.614</td>
<td>0.113</td>
<td>0.393</td>
<td>0.142</td>
<td>0.648</td>
<td>0.122</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.358</td>
<td>0.094</td>
<td>0.321</td>
<td>0.059</td>
<td>0.512</td>
<td>0.186</td>
<td>0.401</td>
<td>0.075</td>
</tr>
<tr>
<td>Terminate</td>
<td>0.109</td>
<td>0.029</td>
<td>0.181</td>
<td>0.033</td>
<td>0.794</td>
<td>0.288</td>
<td>0.277</td>
<td>0.052</td>
</tr>
</tbody>
</table>

*If a sum column is not ideal, that is, the largest value not 1.0, idealize by dividing by largest value in the column.

### Synthesis of the Alternatives in Two Ways

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>BO/CR (from unwtd columns)</th>
<th>bB+oO-cC-rR (from weighted col's)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in table above)</td>
<td>Normalized</td>
</tr>
<tr>
<td>Deploy</td>
<td>2.504</td>
<td>0.493</td>
</tr>
<tr>
<td>Global</td>
<td>1.921</td>
<td>0.379</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.560</td>
<td>0.110</td>
</tr>
<tr>
<td>Terminate</td>
<td>0.090</td>
<td>0.018</td>
</tr>
</tbody>
</table>
ANWR

Arctic National Wildlife Refuge
ANWR Situation

- ANWR- Arctic National Wildlife Refuge
- Size- 19 Million Acres; Area 1002-1.5 Million Acres of Coastal Plain
- Protected in 1960-Eisenhower
- Land Compromise Carter Admin.
- Efforts to Re-open for Exploration- Bush
- Counter efforts to stop Exploration
Introduction to the ANWR situation

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. This coastal plain area, also known as area 1002, was originally protected in 1960 by President Eisenhower. 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. Similarly the first Bush Administration 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 9/11 terrorist attacks, sees drilling in ANWR as vital not only for economic but also for national security reasons. Several environmental groups consider ANWR a great American natural treasure and one of the last places on earth where an intact expanse of arctic and sub-arctic lands remain protected. They feel that the habitat, the wildlife, and the culture need to be protected from the exploration of gas and oil.

The following Super Decisions model was formed as a way to arrive at a decision regarding the use of this land. This model incorporates pair-wise 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 the land we are able to come to a plausible conclusion as to whether or not this area should be further explored.
Overview of Model

[Diagram showing a model with stages: Goal, Criteria, and Model with subcategories of Benefits, Costs, Opportunities, and Risks.]
# Cluster Matrix Overview

<table>
<thead>
<tr>
<th>Economic</th>
<th>Benefits</th>
<th>Costs</th>
<th>Opportunities</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local labor increase</td>
<td>Labor</td>
<td>Local business</td>
<td>Reliance on Foreign Oil</td>
</tr>
<tr>
<td></td>
<td>Less reliance on foreign oil</td>
<td>Raw Materials</td>
<td>ROI</td>
<td>Investments</td>
</tr>
<tr>
<td></td>
<td>Local resources</td>
<td>Infrastructure</td>
<td>Exports</td>
<td>Other energy sources</td>
</tr>
<tr>
<td></td>
<td>Property values</td>
<td>Property Value</td>
<td>Tax</td>
<td>Jobs</td>
</tr>
<tr>
<td></td>
<td>Taxes</td>
<td>Taxes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political</td>
<td>Taxes</td>
<td>Assessment Time</td>
<td>Lobbying</td>
<td>Local image</td>
</tr>
<tr>
<td></td>
<td>Less reliance on foreign oil</td>
<td>Political Fallout</td>
<td>Clout</td>
<td>National image</td>
</tr>
<tr>
<td></td>
<td>Elections</td>
<td>World wide instability</td>
<td>National support</td>
<td>Elections</td>
</tr>
<tr>
<td></td>
<td>Clout</td>
<td></td>
<td>Community support</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Revitalization</td>
<td>Environmental</td>
<td>Development</td>
<td>Health</td>
</tr>
<tr>
<td></td>
<td>Development</td>
<td>Crime</td>
<td>Jobs</td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td>Public Programs</td>
<td>Inconvenience</td>
<td></td>
<td>Jobs</td>
</tr>
<tr>
<td></td>
<td>Oil companies contributions</td>
<td>Noise</td>
<td></td>
<td>Cultural</td>
</tr>
<tr>
<td></td>
<td>Taxes to fund Ecological Programs</td>
<td>Cultural</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Benefits - Economic Decision Subnet

Do Not Drill for Oil  .235
Drill for Oil        .765
Benefits - Political Decision Subnet

Do Not Drill for Oil: 0.312
Drill for Oil: 0.688
Benefits - Social Decision Subnet

Do Not Drill for Oil: 0.225
Drill for Oil: 0.775

Reasons:
- Development: 0.301
- Oil Companies contributions: 0.065
- Public Program Funding: 0.106
- Revitalization: 0.340
- Taxes: 0.188
## Overall Priorities

<table>
<thead>
<tr>
<th>Category</th>
<th>Action</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits</strong></td>
<td>Do Not Drill for Oil</td>
<td>.252</td>
</tr>
<tr>
<td></td>
<td>Drill for Oil</td>
<td>.748</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td>Do Not Drill for Oil</td>
<td>.165</td>
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<tr>
<td></td>
<td>Drill for Oil</td>
<td>.835</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>Do Not Drill for Oil</td>
<td>.238</td>
</tr>
<tr>
<td>(most costly)</td>
<td>Drill for Oil</td>
<td>.762</td>
</tr>
<tr>
<td><strong>Risks</strong></td>
<td>Do Not Drill for Oil</td>
<td>.644</td>
</tr>
<tr>
<td>(most risky)</td>
<td>Drill for Oil</td>
<td>.356</td>
</tr>
</tbody>
</table>
Ratings for BOCR

<table>
<thead>
<tr>
<th>Priorities</th>
<th>Benefits</th>
<th>Opportunities</th>
<th>Costs</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priorities</td>
<td>0.425</td>
<td>0.380</td>
<td>0.047</td>
<td>0.148</td>
</tr>
<tr>
<td>Totals</td>
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<td>0.094740</td>
<td>0.298907</td>
</tr>
<tr>
<td>General Public Opinion</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>International Politics</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Amount of Oil</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>
Results

Our Results...

<table>
<thead>
<tr>
<th>Should</th>
<th>77.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should not</td>
<td>22.3%</td>
</tr>
</tbody>
</table>

Alaskan Poll Results

<table>
<thead>
<tr>
<th>Should</th>
<th>78%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should Not</td>
<td>22%</td>
</tr>
</tbody>
</table>

Splitting 6% Unsure Vote

- Should: 75%
- Should not: 19%
- Unsure: 6%