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Technical Report 1615
May 1994

Course-Of-Action Selection Tool (COAST)

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ADMINISTRATIVE INFORMATION

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RV

EXECUTIVE SUMMARY

OBJECTIVE

The Course-Of-Action Selection Tool (COAST) has been developed by the Decision Support Technology Group, Code 44207, at the Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD), San Diego, California, under the Information Management Project sponsored by the Office of Naval Research (ONR) Block Program in Command Systems Technology. COAST implements a general normative decision-making strategy that has been tailored to support an Operational Planning Team (OPT) at a Theater Command in the preparation of a Course-of-Action (COA) Selection Matrix. The COA Selection Matrix is used by the OPT to brief a recommended COA, and alternative COAs, for a mission proposed to the Commander in Chief (CINC).

RESULTS

The inputs to COAST are (1) a set of COAs, (2) a set of criteria, (3) a comparison of the importance of the criteria, and (4) the degree to which each COA satisfies each criterion. Once the user selects the evaluation criteria, the importance of each criterion to the mission is determined. After the initial rating of the criteria, a pairwise comparison can be made to verify and refine the ratings. The consistency of the pairwise ranking is measured and inconsistent pairs are automatically recognized and identified to the user.

After the criteria are ranked by importance, the user evaluates the likelihood that each COA satisfies each criterion. This is accomplished by using probabilistic language, which is referred to in fuzzy logic as a "linguistic possibility scale." Fuzzy logic is then used to combine the importance of each criterion with the possibility that the criterion will be met to compute the possible impact of each criterion on mission success. The results are presented as a COA Selection Matrix. An overall possibility of mission success is computed by combining the possibilities of satisfying the individual criterion. It is a normalized estimate that can be used to meaningfully compare different missions with different evaluation criteria.

RECOMMENDATIONS

Both a Metacard version of COAST for UNIX workstations and a Hypercard version for the Macintosh are available upon request.

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INTRODUCTION

PURPOSE

The Course-Of-Action Selection Tool (COAST) was developed at NRaD to support the preparation of a Course-of-Action (COA) Selection Matrix by the Operational Planning Team (OPT) at USPACOM. The COA Selection Matrix is used to brief the CINC on a recommended COA, and alternative COAs, for a proposed mission.

BACKGROUND

The COA Selection Matrix previously used at USPACOM employs a weighted-sum method for evaluating COAs against a set of selection criteria. It consists of a matrix of scores, where each column in the matrix represents the evaluation of a COA against the criteria. Each criterion is given a multiplicative weighting factor according to its importance. The sum of these weighted scores determines the recommended COA.

The primary benefits of the weighted-sum method are simplicity and identification of the advantages of the COA. These benefits diminish if it is desired to attach additional meaning to the specific numbers in the matrix. In particular, relative risk between criteria is not represented well, and overall mission risk is not represented at all. Diverse missions with different criteria cannot be compared, whether for concurrent evaluation or historical analysis, because the weighted-sum is not a normalized measure of success.

COAST DESCRIPTION

COAST addresses these concerns by using results from the decision theory (Larsen & Dillard, 1989) to provide a decision support methodology that produces a briefing product like the COA Selection Matrix currently in use, but represents an improvement both in terms of method and presentation. Like the weighted-sum, COAST solves multiple criteria decision problems when the criteria have differing degrees of importance. But more importantly, enhancements due to Zadeh and Bellman (1970) and Yager (1977) use fuzzy logic to combine the risk and importance to produce a normalized estimate of the degree that each criterion is met and to provide a normalized estimate of mission success.

The inputs to COAST are (1) a set of COAs, (2) a set of criteria, (3) a comparison of the importance of the criteria, and (4) the likelihood that each COA satisfies each criterion. The evaluation criteria can be entered manually, or selected from a library of criteria listed by category. The categories used in COAST are derived from the *Principles of War* (Clausewitz, 1979) and other sources. Criteria, such as initiative, logistics, and flexibility, are used to evaluate the COAs. Once the user selects the evaluation criteria, the importance of each criterion to the mission is determined. After an initial ranking of the criteria, a pairwise comparison can be made to verify and refine the rankings by using techniques developed by Saaty (1977). The consistency of the pairwise ranking is measured, and inconsistent pairs are automatically recognized for and identified to the user.

After the criteria are ranked by importance, the user evaluates the likelihood that each COA satisfies each criterion. This is accomplished using probabilistic language, referred to in fuzzy logic as a "linguistic possibility scale" (e.g., certain, probable, likely, possible, unlikely, doubtful). Fuzzy logic is then used to combine the importance of each criterion with the possibility that the criterion is met

met to compute the possible impact of each criterion on mission success. If a criterion is less than essential, its impact on mission success is reduced; that is, the possibility of the mission satisfying a criterion is increased if the criterion is less than essential to the mission. (This is essentially equivalent to giving a criterion less weighting in the weighted-sum method.) The results are presented as a COA Selection Matrix that identifies the highest risk criterion for each COA.

An overall possibility of mission success can be computed by combining the possibilities of satisfying the individual criterion. The term possibility is used because the results are analogous to probabilities, but without the requisite rigor. The combination rule, used for obtaining the possibility of mission success, is to take the average of the possibilities of satisfying the individual criterion. While other combination rules can be employed, the average has additive properties like the weighted-sum, yielding results that are comparable to the weighted-sum. The average also approximates the possibility that "most criteria are met." The standard deviation of the individual possibilities about their average is used to determine the statistical significance of mean possibility differences between COAs. In this way, not only the ranking, but also the significance of the ranking of the COAs, is determined. The measure of the possibility of mission success is also an indication of risk, in the sense that the possibility of mission failure is the complement of the possibility of mission success. More importantly, possibility of mission success is a normalized estimate that can be used to meaningfully compare different missions with different evaluation criteria.

COAST USER INTERFACE

The user interface for COAST was originally written in Hypercard for the Macintosh, and subsequently, it was converted to MetaCard for the UNIX/X-Window platform. The Macintosh version is illustrated here. Figure 1 is the Title window for COAST. There are four buttons in the top menu bar: **File, Library, Help and Start.**

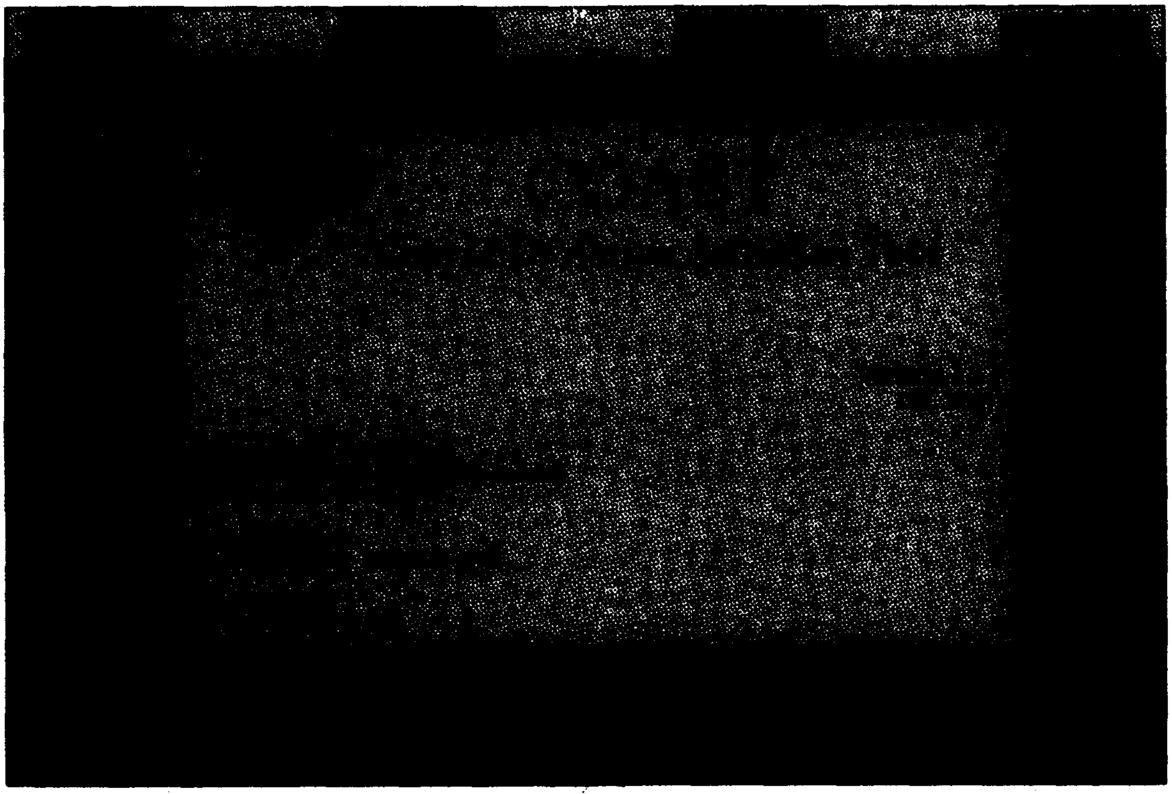


Figure 1. **Title** window.

The **File** button drops down a menu giving the user the options of preparing COAST for a new session, loading a previously saved session, saving the current session, or quitting. To follow along with this description, you can click on the **File** button and select **Open Session** to open the sample *Bangladesh Relief* session delivered with COAST.

Selecting **Library** brings us to the window shown in figure 2. This window allows the user to maintain a library of criteria and their categories for each Mission Type. In the example, the user has added the criterion *Force Availability/Closure Rate* under **Criteria List** to the *MANEUVER* **Criteria Category** for a *DISASTER* **Mission Type**. Selecting the up arrow in the upper right hand corner of the **Library** window brings us back to the **Title** window.

The user begins a session by selecting **Start** from the **Title** window. This brings us to the **List COAs** window shown in figure 3. The user enters the Name of the Mission, *Bangladesh Relief*, selects the Mission Type, in this case *DISASTER*, and lists the COAs. Three COAs have been listed.

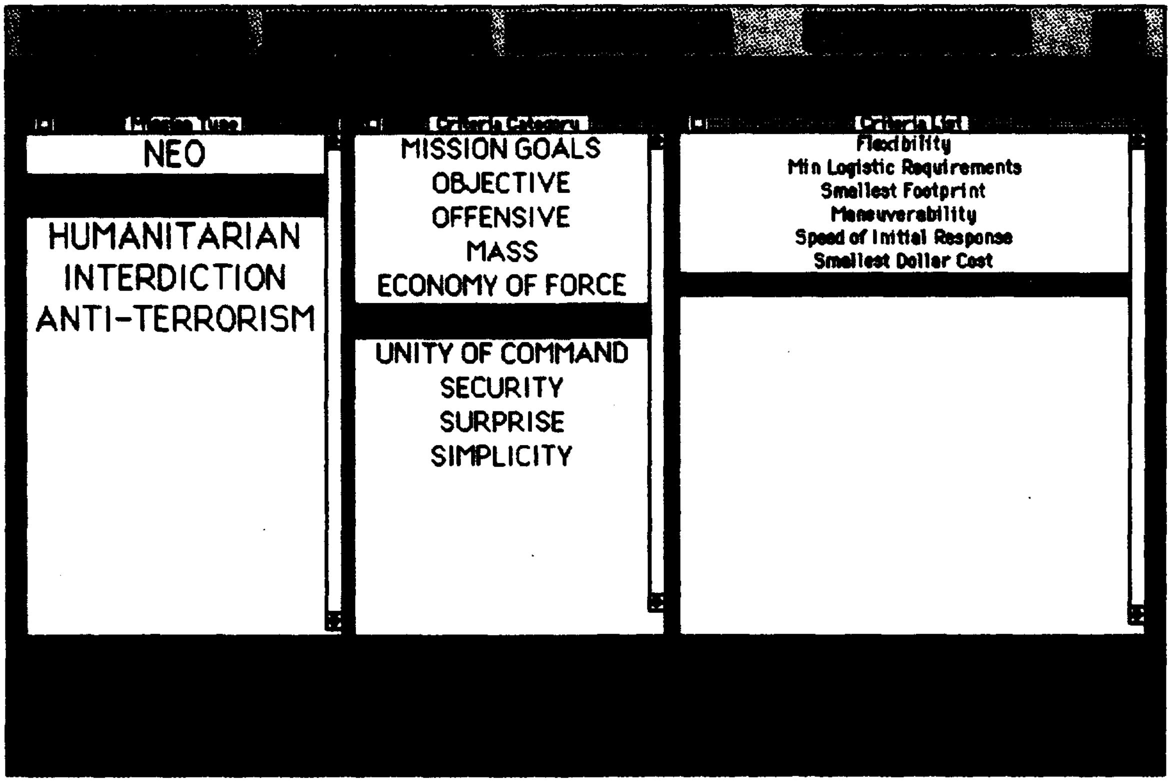


Figure 2. Library window.

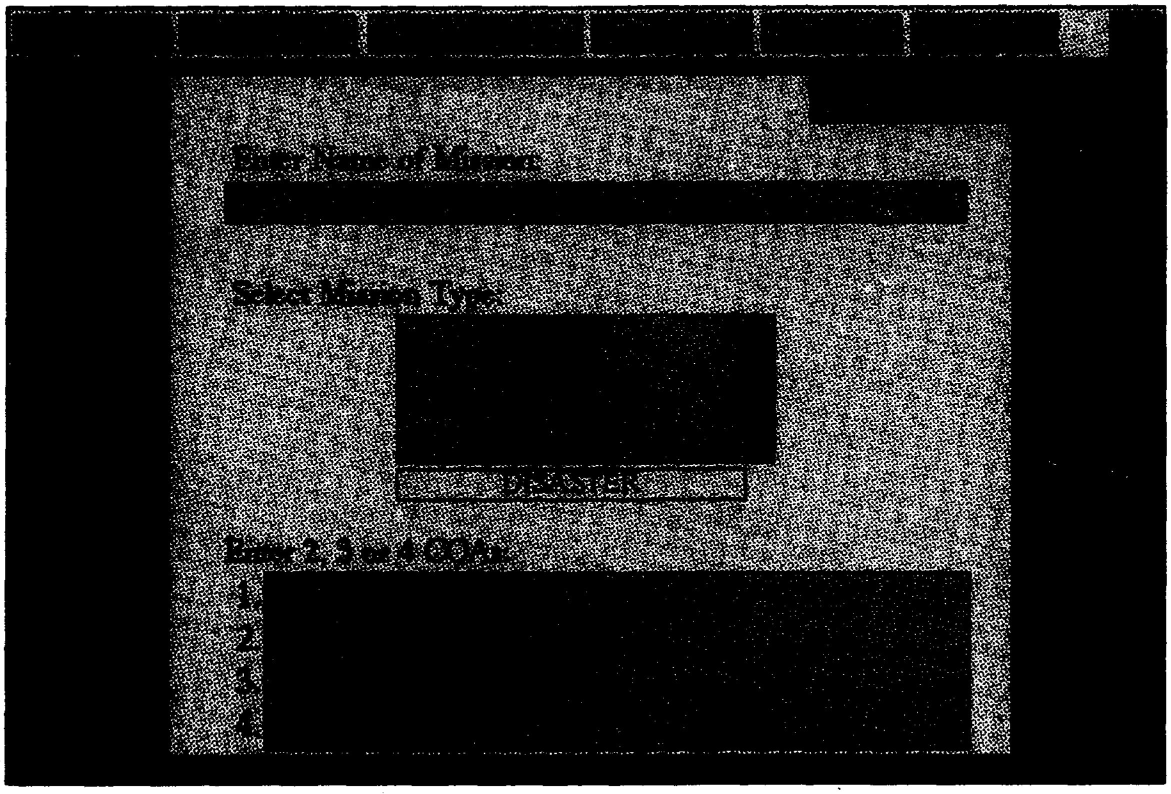


Figure 3. List COAs window.

Next, the user selects **List Criteria** from the menu bar (figure 4). Ten criteria to be used for evaluating the COAs have been entered. They can be selected from the **Criteria List** library, typed in manually, or ported in from an external planning aid. In the example shown, the tenth criterion, *Force Availability/Closure Rate*, has been selected from the **Criteria List** Library as shown by the icon on the right side of the window under **Select Criteria**.

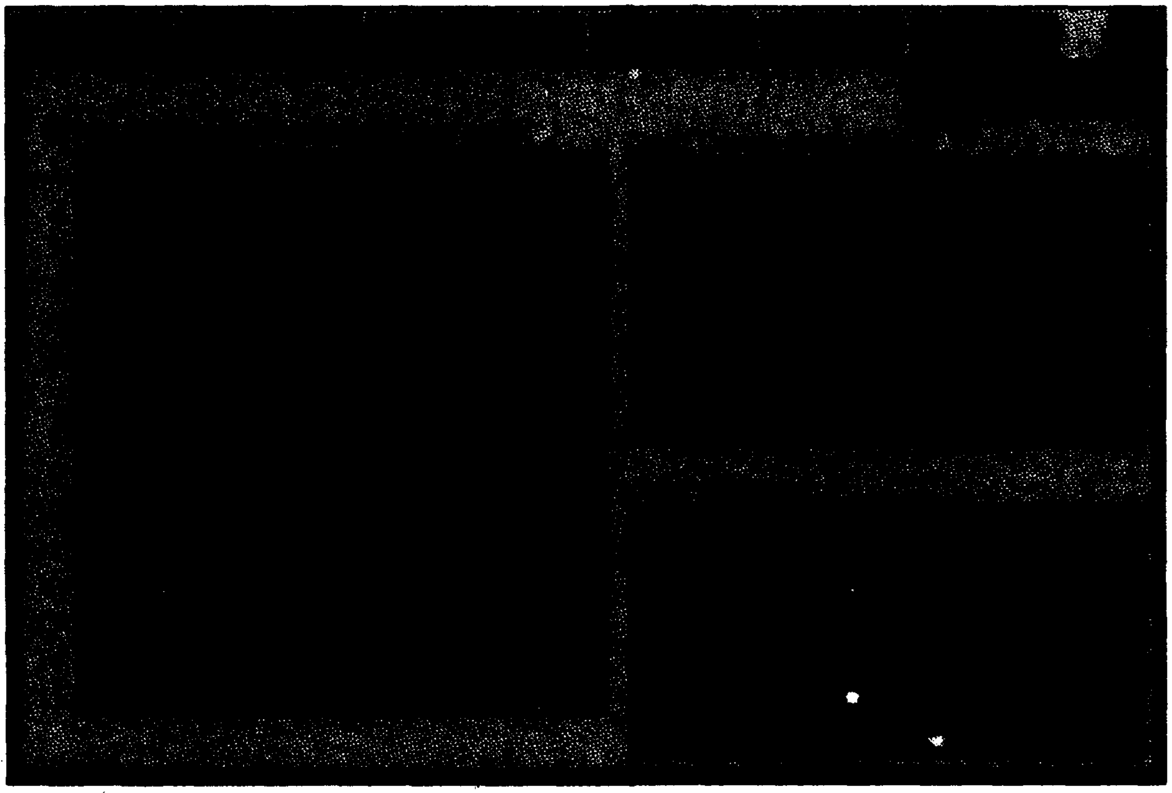
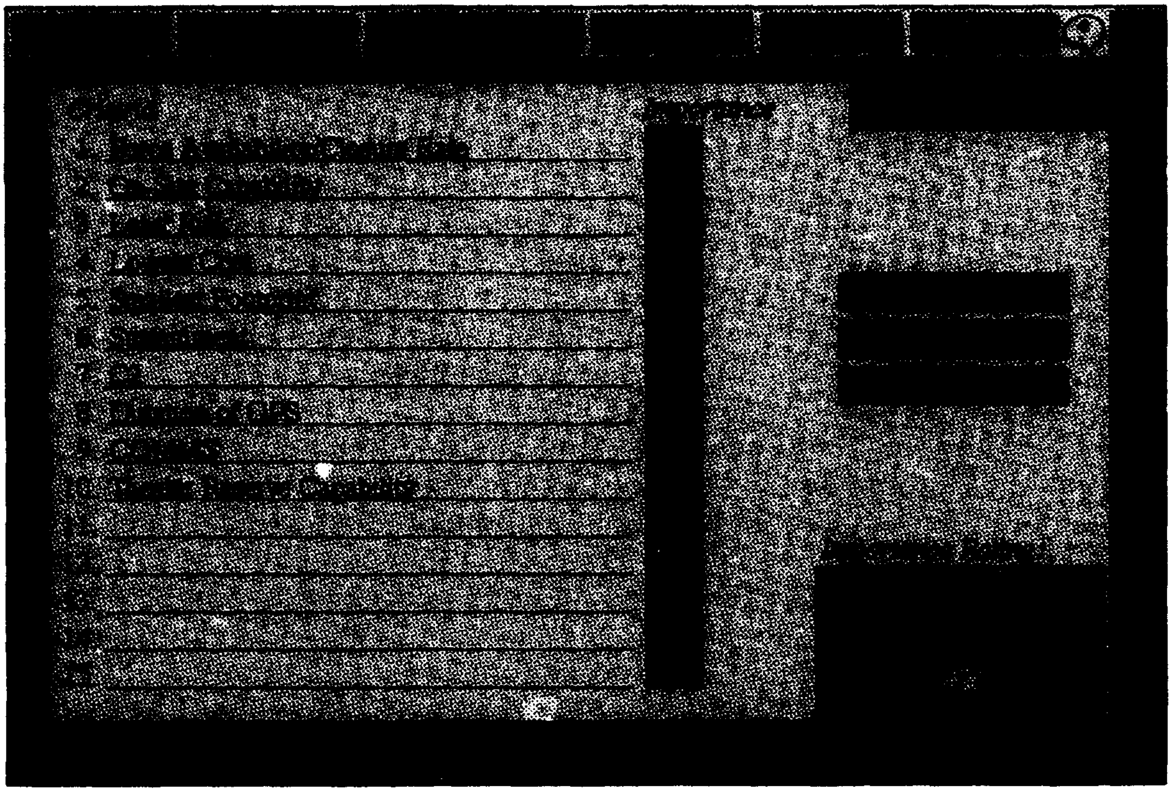


Figure 4. **List Criteria** window.

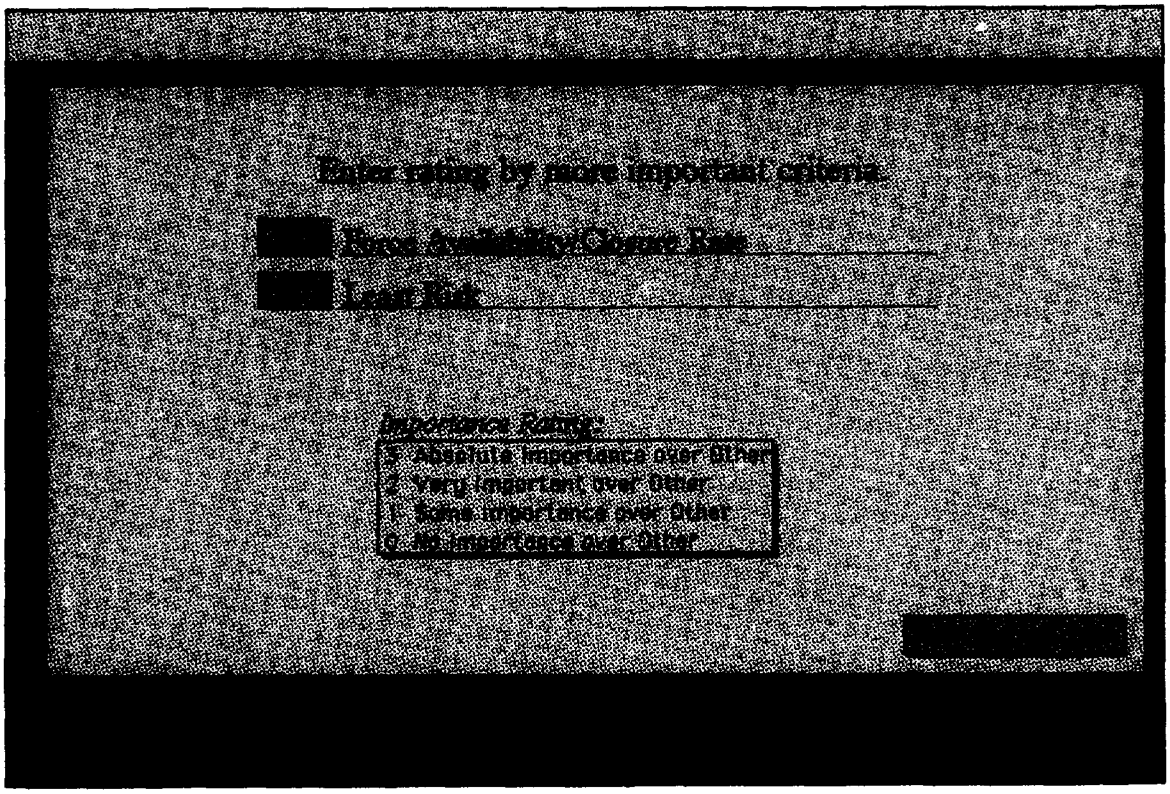
The next step is to evaluate the importance of criteria. The user is given two methods for an initial evaluation: rank and pairwise. If the user chooses the ranking method, then the **Rank Criteria** screen, shown in figure 5, is brought up. The initial ranking is accomplished by selecting one of four Importance Rating measures from the menu in the lower right hand corner. In this case, one criterion is rated (A) *Essential*, two are rated (B) *Very Important*, and seven are rated (C) *Important*.

The Pairwise Evaluation button can now be used to verify the rank scores. Figure 6 shows a comparison being made for two criteria. In the example, *Force Availability/Closure Rate* is rated to have *Some Importance* (a score of 1) over *Least Risk*. Once the pairwise comparisons are done, the user is shown a summary **Pairwise Refinement** window, figure 7. As can be seen, the user has requested to refine the rankings of the top four criteria, and the six resulting pairwise comparisons are shown. In this case, the consistency of the pairwise rankings is rated OK, as seen on the barometer on the right. If the pairwise rankings had not been consistent, the pair causing the greatest discrepancy would have been identified to the user. "Fixing" discrepancies is discretionary because they do not invalidate the results. Next, we return to the **Rank Criteria** window, figure 8, where the original ranking **(Old)** and pairwise ranking **(New)** are shown. In this case, we will **Make Change** to the **New** numbers, figure 9.



1. Force Availability/Closure Rate
2. Combat Capability
3. Least Risk
4. Least Cost
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. Flexible Reserve Capability

Figure 5. **Rank Criteria** window.



Enter rating by more important criteria.

Force Availability/Closure Rate

Least Risk

Importance Rating:

3 Absolute Importance over Other
2 Very Important over Other
1 Some Importance over Other
0 No Importance over Other

Figure 6. **Pairwise Comparison** window.

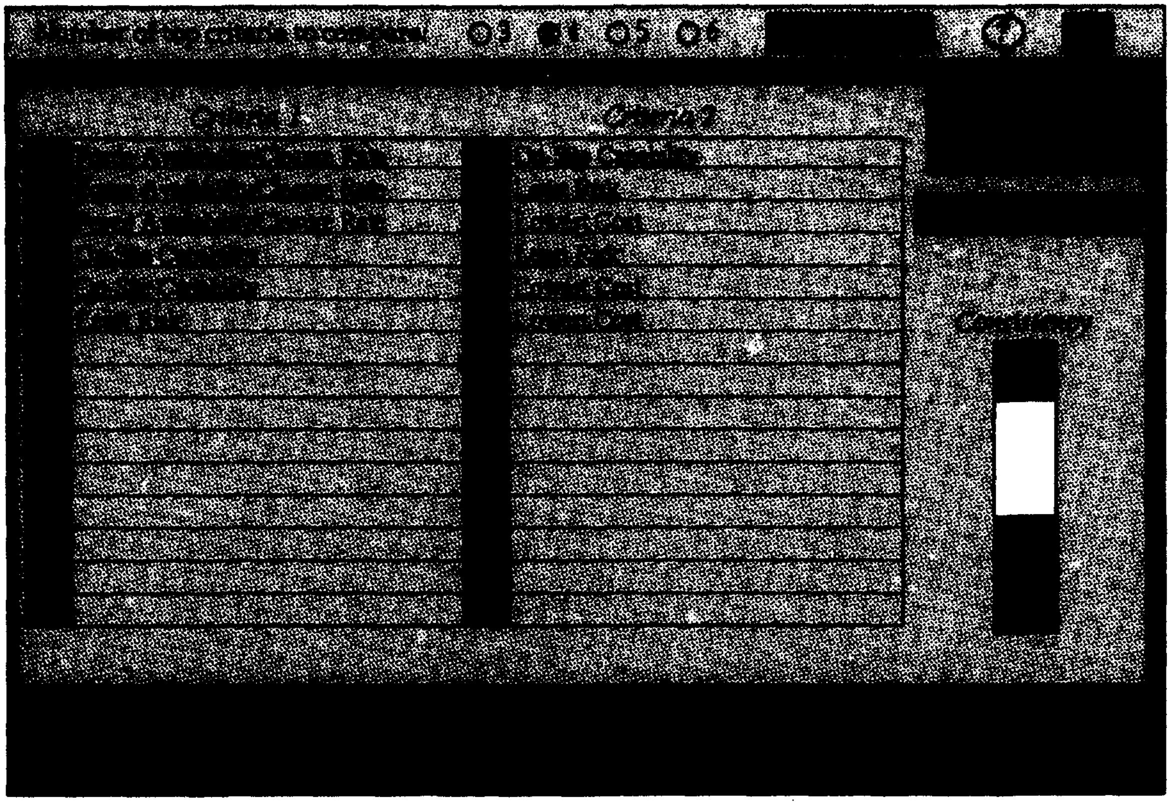
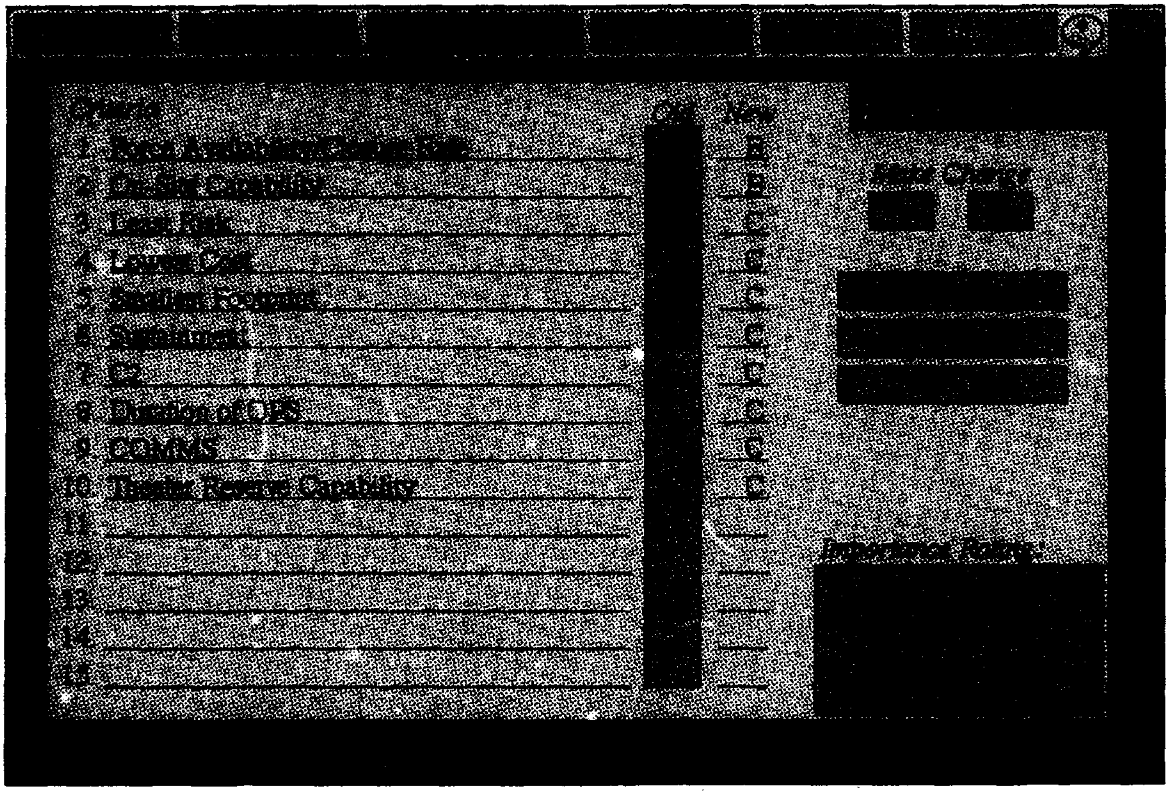
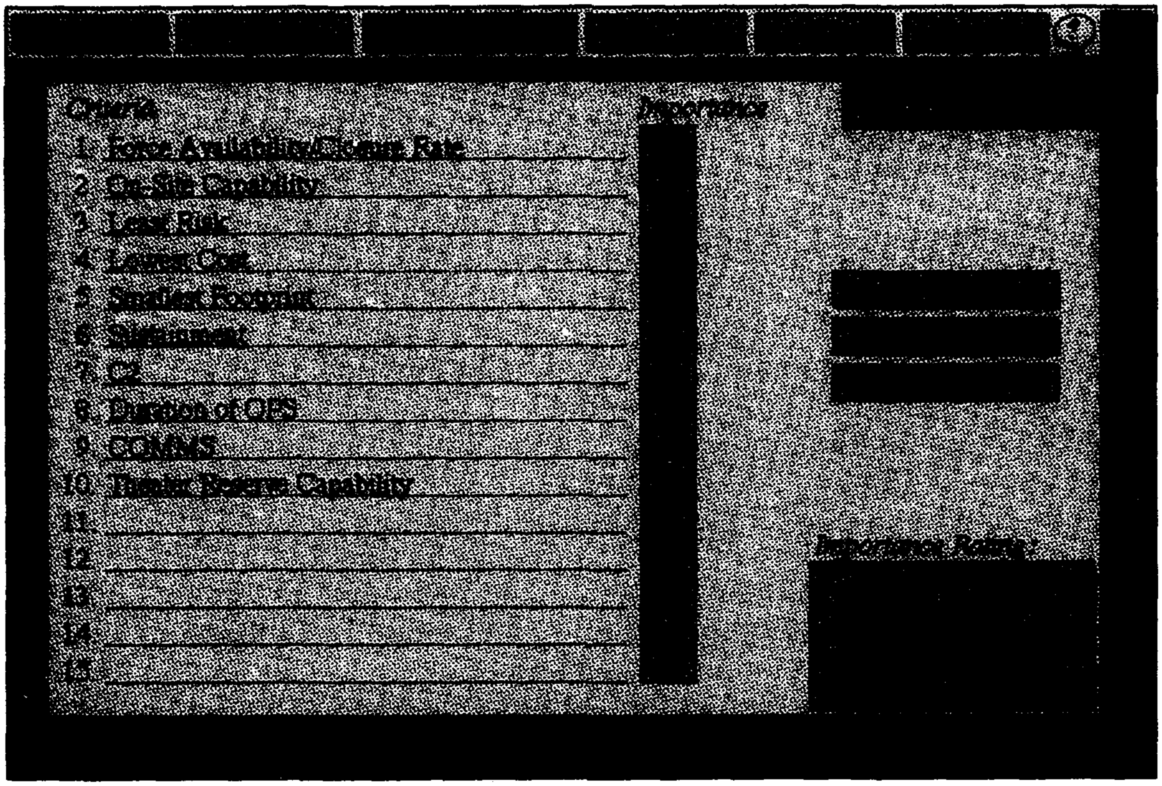


Figure 7. **Pairwise Refinement** window.



Criteria	Old	New
1 Force Availability/Combat Rate		B
2 On-Site Capability		B
3 Least Risk		C
4 Lowest Cost		C
5 Smallest Footprint		C
6 Sustainment		C
7 C2		B
8 Duration of OPS		C
9 COMMS		C
10 Theater Reserve Capability		C
11		
12		
13		
14		
15		

Figure 8. **Old versus New Rank Criteria** window.



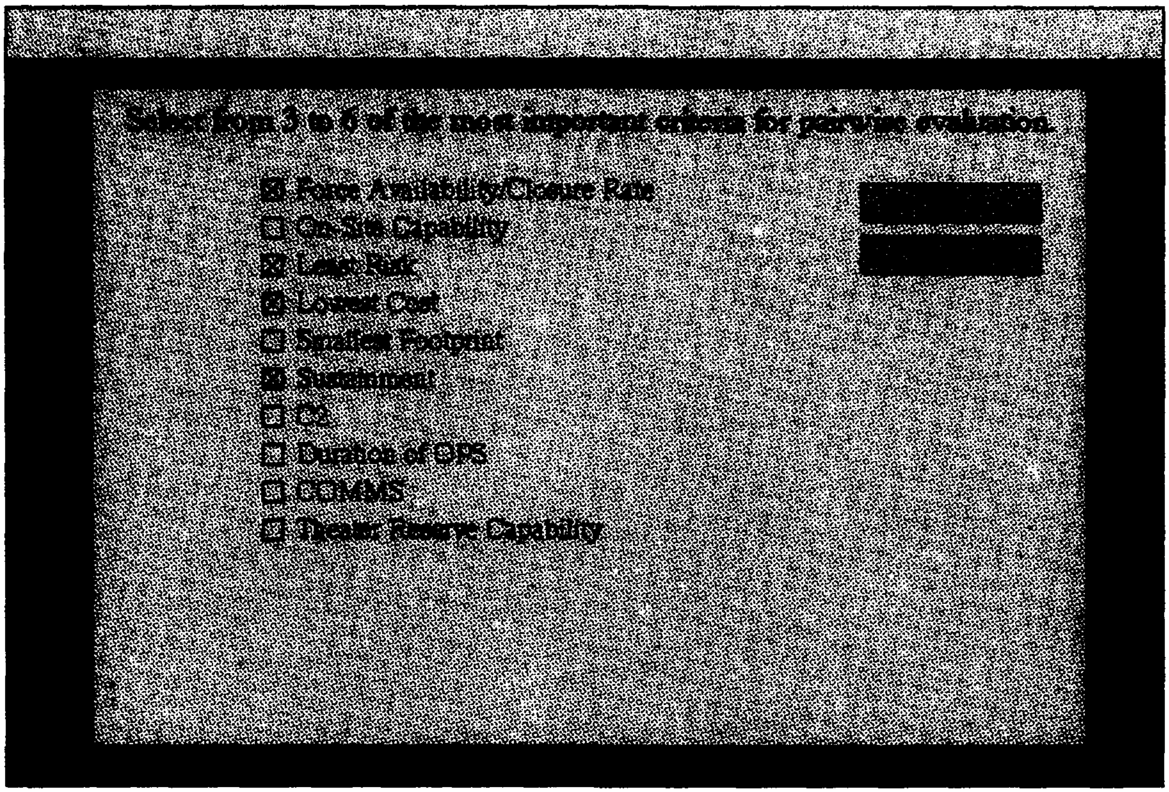
1. Force Availability/Closure Rate
2. On-Site Capability
3. Least Risk
4. Lowest Cost
5. Smallest Footprint
6. Sustainment
7. C2
8. Duration of OPS
9. COMMS
10. Theater Reserve Capability
11.
12.
13.
14.
15.

Figure 9. Final **Rank Criteria** window.

It is possible to initially evaluate the criteria using the pairwise method. If the user initially chooses this method, then the ranking screen is skipped, and the user must select from three to six of the most important criteria to perform the pairwise method. The remaining criteria are automatically given a *Some Importance* rating. No more than six criteria can be evaluated using the pairwise method because any more than six would generate excessive pairs to compare. Figure 10 shows an example of selecting four criteria for pairwise evaluation.

In a group session, the rank and pairwise methods for establishing criteria importance can be used iteratively, or in combination, until the results are clearly understood and mutually agreed upon.

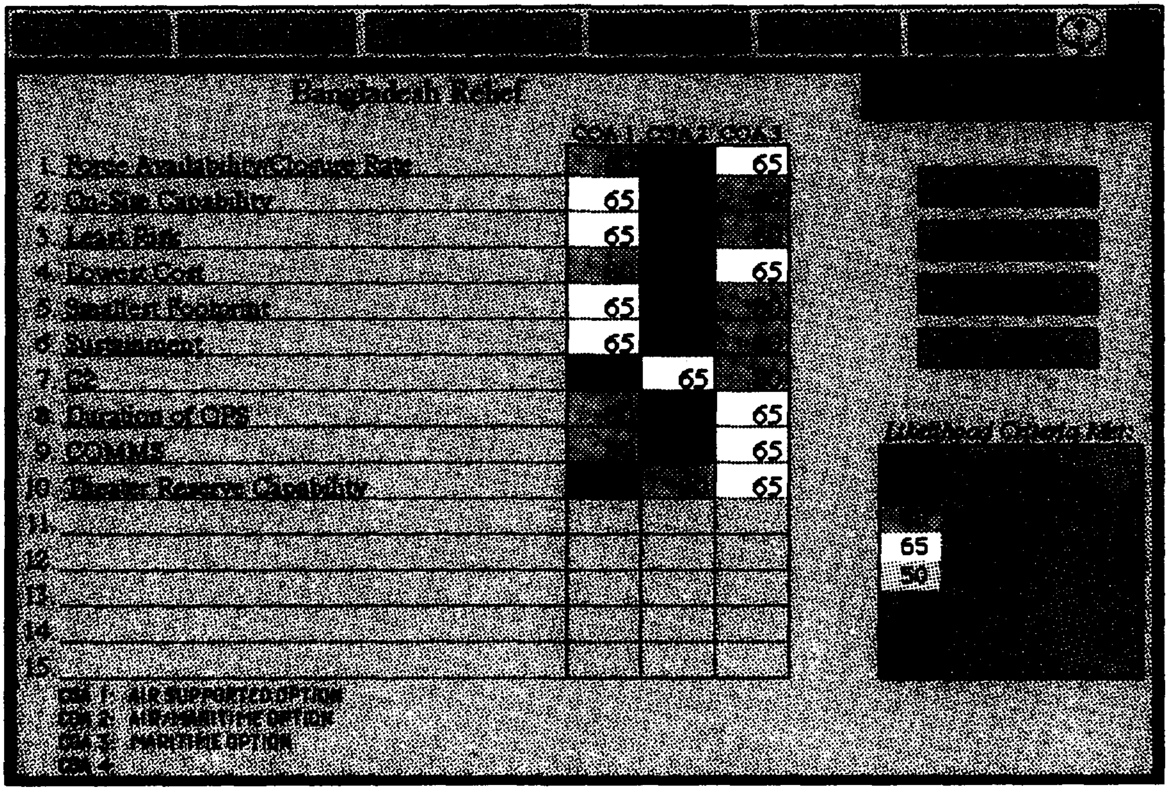
Next, we select the **Evaluate COAs** window, figure 11. The three COAs are listed against the criteria. The user evaluates the likelihood that each COA satisfies each criterion using the **Likelihood Criteria Met** menu of eight possibilistic terms that range from **Certain** to **No Chance**. The terms are numerically coded and color coded. The numerical values are possibilities used in fuzzy computations. The **Hide Colors** and **Hide Scores** buttons give users the option of what to display. Hiding colors and scores, until the evaluation process has been completed, assists the user in making unbiased judgments. Until all entries are made and mutually agreed upon, it is highly recommended that colors and scores be hidden during group sessions.



Select from 3 to 6 of the most important criteria for pairwise evaluation.

☒ Force Availability/Closure Rate
☐ On-Site Capability
☒ Least Risk
☒ Lowest Cost
☐ Smallest Footprint
☒ Sustainment
☐ C2
☐ Duration of OPS
☐ COMMS
☐ Theater Reserve Capability

Figure 10. Pairwise Criteria Selection window.



Bangladesh Relief

	COA 1	COA 2	COA 3
1. Force Availability/Closure Rate			65
2. On-Site Capability	65		
3. Least Risk	65		
4. Lowest Cost			65
5. Smallest Footprint	65		
6. Sustainment	65		
7. C2		65	
8. Duration of OPS			65
9. COMMS			65
10. Theater Reserve Capability			65
11.			
12.			
13.			
14.			
15.			

COA 1: AIR SUPPORTED OPTION
COA 2: AIR/MARITIME OPTION
COA 3: MARITIME OPTION
COA 4:

Figure 11. Evaluate COAs window.

The user can list the strengths, weaknesses, and assumptions associated with each evaluation, figure 12, by clicking the **More Info** button. In the upper right-hand corner is an explanation of the relationship between (1) the likelihood the criterion is met by the COA, (2) the importance of the criterion to the mission, and (3) the likelihood the criterion is met by the mission (the computed score).

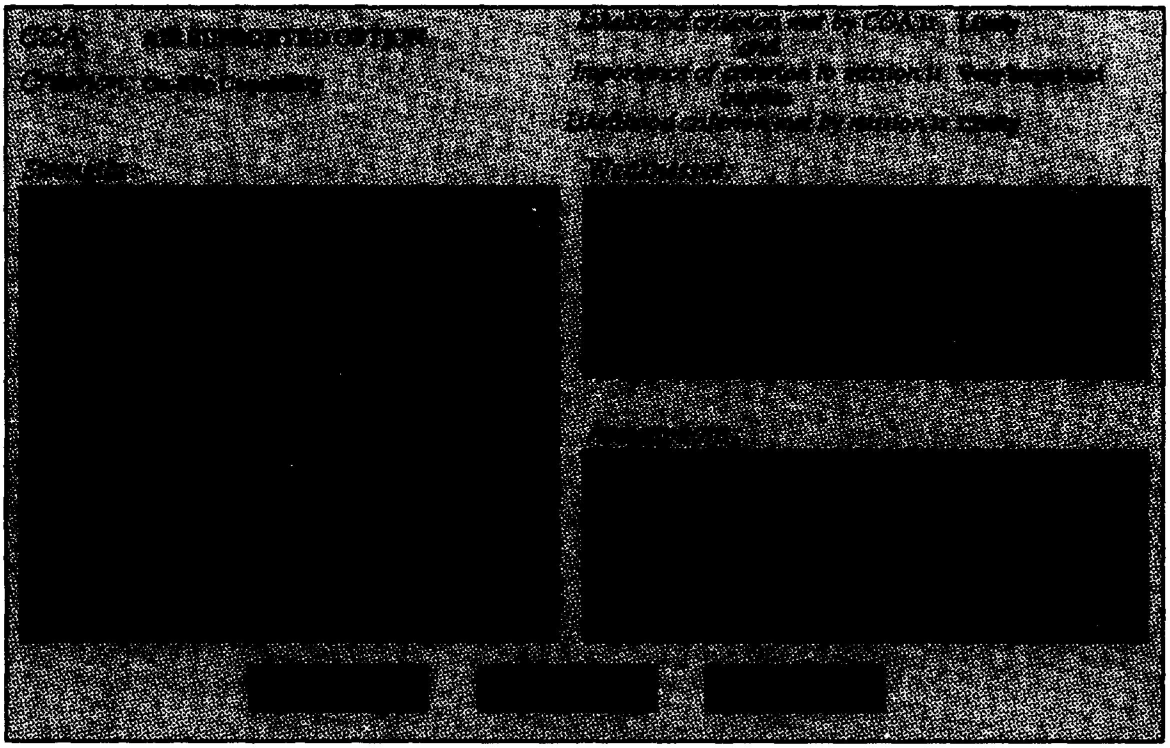


Figure 12. **More Info** window.

From the **More Info** window, the user can compare the current evaluation with another, figure 13. This feature should aid in recalling the reasoning and arguments behind the evaluation results. The **More Info** windows can be easily accessed from the **Summary** window as an aid to briefing the **COA Selection Matrix**.

Once the **Evaluate COAs** window is filled out, the user can select the **Compute** window, figure 14, showing the results of the fuzzy method for combining the evaluation of the COAs with the importance of the criteria. These results are shown in the three columns: COA 1, COA 2, COA 3. Below the columns are the averages of the scores in percent. The average is to be interpreted as the possibility that "most criteria" will be met and is called the **Measure of Effectiveness** (MOE). In this example, the possibility that COA 1 meets most criteria is 86%. The ranking of the COAs is determined using the MOEs. The **Significance test for MOE difference**, however, can provide additional insight into the true ranking of the COAs. This test determines whether, or not, there is at least a 50% possibility that the difference in rank could occur by chance, given the distribution of scores in the matrix. In the example shown, the difference test statistic is 5. Since the MOE mean of COA 2 is 6 points greater than the mean of COA 1 (i.e., 92% vice 86%), COA 2 is ranked first while COA 1 is ranked second. Since the difference between COA 1 and COA 3 is not greater than, nor equal to, 5, COA 3 can also be ranked second; that is, there is a 50% possibility that COA 2 should be

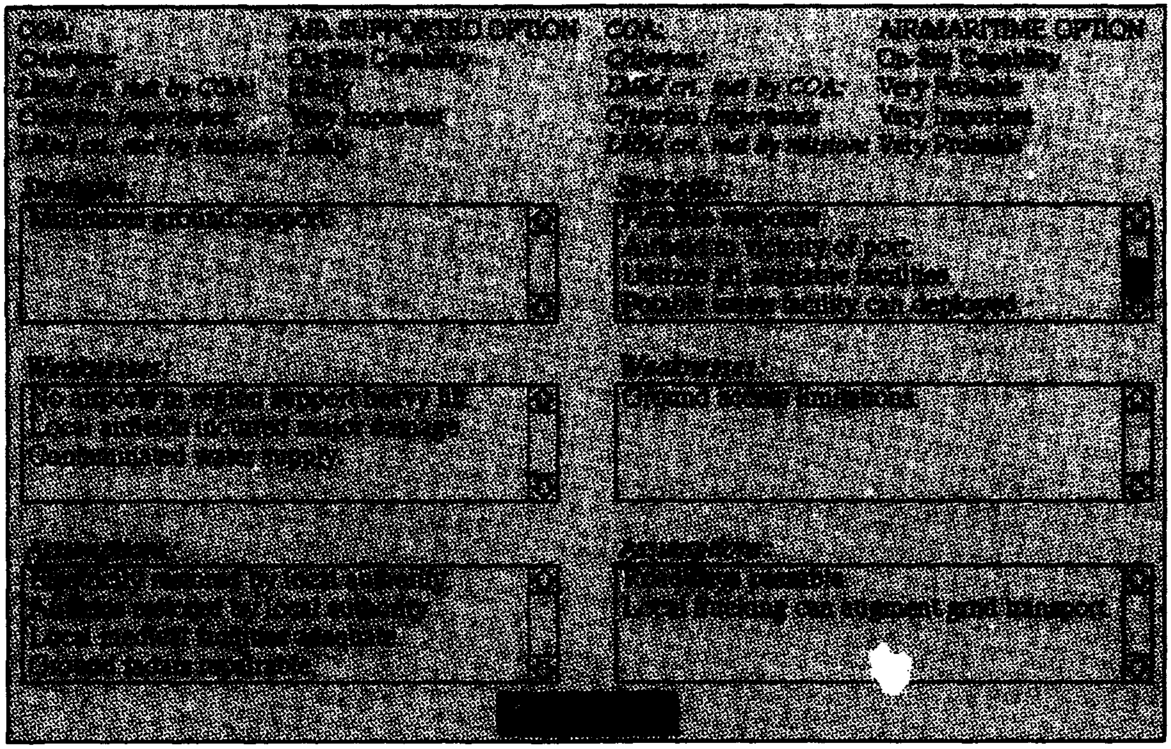


Figure 13. Compare window.

Figure 14. Compute window.

ranked better than COA 1 or COA 3, but there is less than 50% possibility that COA 1 should be ranked better than COA 3. If the difference in MOE between the best and worst COA had been less than the **Significance test for MOE difference**, then all COAs could be considered equally valid since the differences are not statistically significant.

If the user chooses to display the results by using the three-color adjustable scale, which is the case in figure 14, a meter will be displayed at the bottom of the window allowing the user to adjust the scale. In figure 14, the user has selected 75% and 90% as the boundaries between the three colors. The three colors are green, yellow, and red meaning good (no risk), indifferent (some risk) and bad (high risk), respectively. If the user chooses the eight-color absolute scale, a legend for colors' possibilistic meanings will appear at the bottom of the window.

The **Summary** window is the COAST version of the COA Selection Matrix. Like the **Compute** window, the results can displayed in three or eight colors. The eight-color summary is shown in this example. The MOEs of the COAs are shown at the bottom. The relative importance of the criteria are indicated by stars on the left of the criteria listing. Recall that the first two criteria are considered more important than the rest.

When reviewing the **Summary** window, the user may select a cell for **More Info**, as shown in figure 12, and continue to select an additional cell for comparison, as shown in figure 13. This feature should be useful as a briefing aid to recall specific reasons behind the final evaluation results.

THE WEIGHTED-SUM SELECTION MATRIX

The COA selection matrix, figure 15, is to be compared with a corresponding weighted-sum selection matrix, figure 16. The COAs are each ranked (against the criteria) with a score of 1, 2, or 3 in figure 16. The first two criteria are given twice the weight of the remaining criteria. These scores are added, and the total result is shown at the bottom. The scores in figure 16 are intended to be comparable in terms of results to those in figure 15.

The primary difference between the weighted-sum and fuzzy logic result is seen within the matrix. In the weighted-sum version, it appears that COA 2 is the better choice because it best satisfies the two most important criteria (i.e., scores of 6). In the fuzzy logic result shown in figure 15, it appears that COA 2 is preferred because it satisfies most criteria best and COA 1 and COA 3 have obvious weaknesses; that is, COA 1 does not support On-Site Capability and COA 3 does not *Support Force Availability/Closure Rate*. These weaknesses in COA 1 and COA 3 are not evident in figure 16. The conclusion reached is that the weighted-sum shows the strengths of a COA, but fuzzy logic shows both strengths and weaknesses with equal emphasis.

It is also important to note that weighted-sum scores have no meaning other than relative scoring of the specific COAs in the matrix. On the other hand, the fuzzy logic computed possibilities are normalized measures of success. This means they can be used to meaningfully compare diverse missions with different selection criteria.

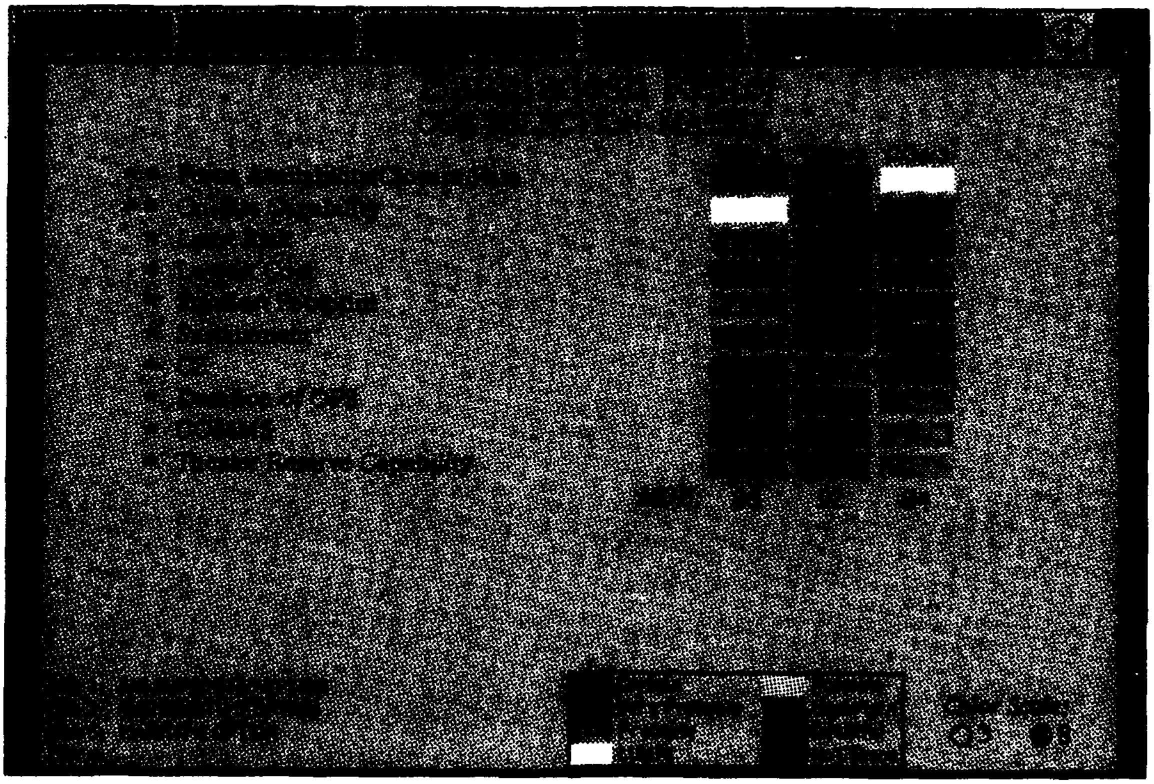
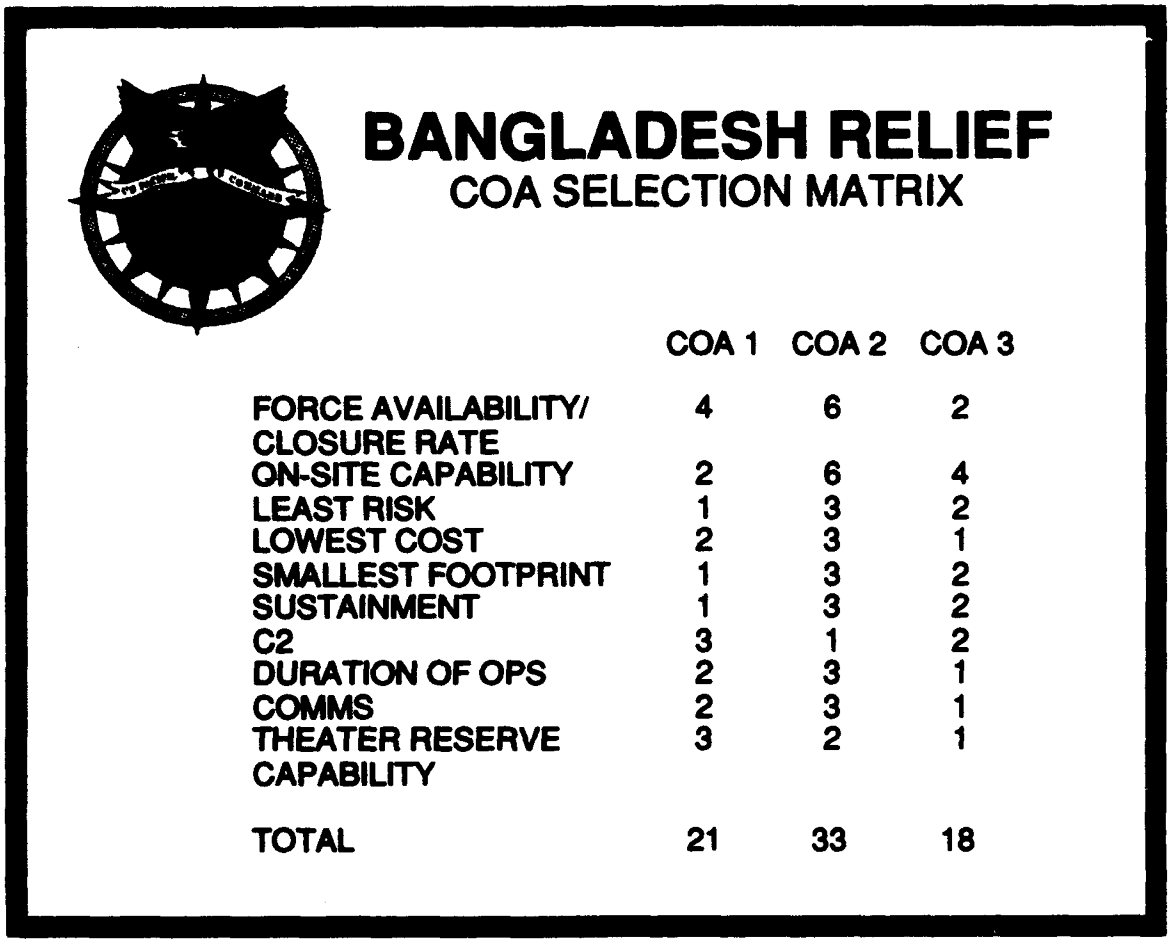


Figure 15. Summary window.



BANGLADESH RELIEF

COA SELECTION MATRIX

	COA 1	COA 2	COA 3
FORCE AVAILABILITY/ CLOSURE RATE	4	6	2
ON-SITE CAPABILITY	2	6	4
LEAST RISK	1	3	2
LOWEST COST	2	3	1
SMALLEST FOOTPRINT	1	3	2
SUSTAINMENT	1	3	2
C2	3	1	2
DURATION OF OPS	2	3	1
COMMS	2	3	1
THEATER RESERVE CAPABILITY	3	2	1
TOTAL	21	33	18

Figure 16. Weighted-sum selection matrix.

DECISION MAKING

Normative decision theory postulates decision making as an act of rational choice. Given a set of possible choices for a given situation, the optimal choice is the one that meets a set of selection criteria "best." Typically, "best" is determined by utility analysis, the weighted-sum method being the most commonly used version. The advantage of the weighted-sum is that it allows users to express their preferences in simple, easily understood ways. The disadvantage is that it does not have substantive interpretation.

Probabilistic reasoning, another approach that is used, would allow a more rigorous calculation of the probability that a particular decision is the correct one. While this approach has merit, it requires the user to determine (1) the probabilities that the criteria are met by a given decision choice, (2) the conditional probabilities quantifying the dependence of a successful decision outcome on meeting each criterion, and (3) specification of the dependence between criteria. This implies a model of the problem space with quantitative evaluation criteria derived from the model.

A compromise to the probabilistic approach uses fuzzy sets to represent subjective criteria and incomplete information about a situation (Zadeh & Bellman, 1970). In many ways, fuzzy reasoning occupies a middle ground between probabilistic reasoning and utility analysis. Fuzzy logic has the advantages that it approximates probabilistic reasoning in a tractable way, and it uses natural language evaluation, which is straightforward and intuitively appealing. Human beings deal naturally with subjective or fuzzy information. Typically, we speak of tall men in easily understood conversation, although in actual fact, we cannot precisely define what a tall man is. Likewise, by its nature, military command and control deals extensively with imprecise knowledge and subjective goals. There is never enough information, or time, to completely analyze a situation to make a decision. Yet, humans beings tend to perform reasonably well under such circumstances to arrive at good decisions, in spite of ambiguity and confusion.

On the other hand, the volume of information and the pace of operations of modern warfare preclude the time-consuming and man-intensive processes of the past. In addition, despite humankind's best efforts, human feelings and preferences remain inconsistent and intransitive, often leading to judgmental errors. The battlefield of the future has an overriding need for computerized information and decision support systems that support a rapid, reliable, and effective assimilation of timely information for planning, decisions and command actions.

FUZZY LOGIC

Zadeh (1965) formulated the initial statement of fuzzy set theory. Fuzzy set theory is based on a recognition that certain sets have imprecise boundaries. Typically, we speak of tall men or expensive homes. Membership in such sets, or classes of objects, is not characterized by either/or, but are sets in which membership can be adequately considered in terms of degrees. Fuzzy logic is concerned with the formal principles of approximate reasoning and with precise reasoning viewed as a limiting case.

Natural language evaluation is an important aspect of fuzzy reasoning and COAST. Figure 17 illustrates a typical linguistic likelihood scale that has been derived from extensive surveys. In COAST, the user is asked to specify the likelihood that a given COA satisfies a selection criterion, using this scale.

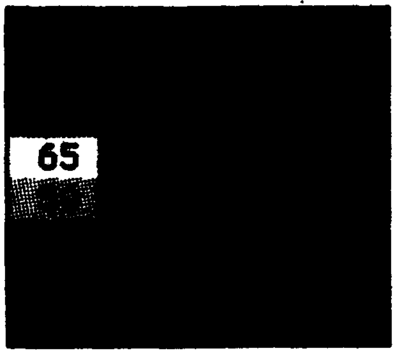


Figure 17. A linguistic likelihood scale.

The primary fuzzy operation of concern here is the notion of exponentiation as introduced by Zadeh (1965). It is used in COAST to express the importance of the criteria to mission success. In possibilistic terms, it is used to approximate the conditional dependence of mission success on the individual criterion. Let p_j represent the possibility that criterion j is satisfied by a particular COA. Let P_j be the possibility representing the dependence of mission success on criterion j. If criterion j is essential to the mission, then $P_j = p_j$. If criterion j has no importance to mission success, then $P_j = 1$, no matter what the value of p_j, that is, mission success is certain, $P_j = 1$, in so far as criterion j is concerned, because mission success does not depend on criterion j. In general, the exponentiation operation as defined by Zadeh (1965) states that

$$P_j = p_j^{I_j}$$

where

$$0 \le I_j \le 1.$$

In this formula, I_j is the importance of criterion j to mission success. If criterion j is essential, $I_j = 1$. If criterion j has no importance, $I_j = 0$.

In COAST, the user is allowed to define a criterion as Important, Very Important, or Essential. In fuzzy logic, these terms are represented by the exponentiation operation as follows:

$P_j = p_j^{1}$, is criterion j is Essential.

$P_j = p_j^{3/4}$, if criterion j is Very Important.

$P_j = p_j^{2/4}$, if criterion j is Important.

$P_j = p_j^{1/4}$, if criterion j is Somewhat Important.

In the terminology of Zadeh (1965), $I_j < 1$ reduces the grade of membership, but in such a manner, that large membership values p_j are reduced much less than small ones. In the extreme of large membership, $p_j = 1$ results in $P_j = 1$, no matter what value I_j assumes.

COA SELECTION METRIC

An overall possibility of mission success P_s can be computed by combining the possibilities of satisfying the individual criterion. It was decided that the possibility that the average of the possibilities is the preferred metric, primarily because it has properties similar to the weighted-sum currently in use. The average was found to be a good approximation to the possibility that "most criteria are met;" thus, the COA selection metric, or estimate of the possibility of mission success, is

$$\text{Selection Metric} = P_s = \mu = \frac{1}{N} \sum_j p_j^{I_j} .$$

The standard deviation of the individual possibilities about their mean is used to determine the statistical significance of mean possibility differences between COAs by

$$\text{Selection Metric} = t - \text{test} = \frac{\mu_2 - \mu_1}{2\sigma} .$$

In this way, not only the ranking, but also the significance of the ranking of the COAs is determined.

PAIRWISE CRITERIA EVALUATION

The next problem discussed is that of obtaining a scale for measuring the importance of each criterion. One method is the straightforward ranking of the criteria. Ranking is a simple way to express preferences; however, it is well known that it may hide user uncertainty and bias. A second method is provided in COAST, which is intended to overcome this drawback. It is the pairwise comparison method developed by Saaty (1972). It allows an overall ranking of criteria to be determined from simpler pairwise comparisons. It also allows the consistency of the results to be measured and it identifies those pairwise evaluations that are inconsistent with the overall pairwise evaluation. Its disadvantage is that for n criteria, n(n−1)/2 paired comparisons must be made. In COAST, we limit the number of criteria compared pairwise to 6, resulting in a maximum of 15 pairs to compare.

Saaty's (1977) procedure for obtaining a ratio scale, for a group of elements based upon a paired comparison of each of the elements, has also been used by Yager (1977) to obtain the values of subjective probabilities from a decision-maker. For n criteria, we ask the decision-maker to compare the criteria in n(n−1)/2 paired comparisons. In particular, for each case where criterion i is more important that criterion j, a value a_{ij} is assigned from table 1.

Table 1. Pairwise Comparison Scale.

Level of Importance	Definition
0	No importance over the other
1	Some importance over the other
2	Very important over the other
4	Absolute importance over the other

Having obtained the above judgments, an n × n matrix B is constructed, such that

$$(1)\ b_{ii} = 1 ,$$

$$(2)\ b_{ij} = a_{ij} , i \neq j ,$$

$$(2)\ b_{ij} = \frac{1}{b_{ji}} .$$

Saaty (1972) shows that the eigenvector corresponding to the maximum eigenvalue, λ_{max}, of B is a cardinal ratio scale, or absolute ranking, of the criteria. The measure of inconsistency derived by Saaty (1972) is

$$\sqrt{\frac{\lambda_{max}-n}{2n-2}} .$$

Larsen and Dillard (1989) derive an algorithm that identifies the most inconsistent pairs in the matrix.

CONCLUSION

Fuzzy sets provide new fertile tools for investigating multiple criterion decision problems. By using a fuzzy set, we are dealing in a very universal concept of "the degree to which an alternative satisfies a criterion," something that can be understood for any criterion. Fuzzy sets also provide a mathematical structure for manipulating vague ideas that become very common in complex multiple-criteria problems.

Fuzzy evaluation with COAST provides a measure of the possibility of mission success. This is an indication of overall risk, in the sense that the possibility of mission failure is the complement of the possibility of mission success. More importantly, possibility of mission success is a normalized estimate that can be used to meaningfully compare different missions with different evaluation criteria. These are the benefits of fuzzy reasoning that utility analysis does not provide. Utility analysis can determine the strengths of a COA, but fuzzy logic shows both strengths and weaknesses with equal emphasis.

Fuzzy logic was "invented" to permit heuristic solutions to otherwise intractable problems in probability and logic. The term "possibility" has been coined to denote a fuzzy solution because it is analogous to, or "loosely" related to, probability. The preferred "possibility scale" is the "linguistic likelihood scale." The numerical scores from 0 to 1 also represent a "possibility scale;" however, they are subjective and cannot be correctly interpreted as probabilities. It may be that numerical results should not be presented as outputs from COAST; however, they remain because they are useful in comparing the relative "scores" of alternate decisions, even if their absolute meaning may be in doubt.

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The Course-of-Action Selection Tool (COAST) implements a general normative decision-making strategy that has been tailored to support an Operational Planning Team (OPT) at a Theater Command in the preparation of a Course-of-Action (COA) Selection Matrix. The COA is used by the OPT to brief a recommended COA, and alternative COAs, for a mission proposed to the Commander in Chief (CINC). A set of COAs, a set of criteria, and a comparison of the importance of the criteria are used as inputs to COAST. The criteria are ranked by importance and the user evaluates the likelihood that each COA satisfies each criterion by using a linguistic possibility scale from fuzzy logic. The results are presented as a COA Selection Matrix from which an overall possibility of mission success is computed. It is a normalized estimate that can be used to meaningfully compare different missions with dissimilar evaluation criteria.

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