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A Prototype Aid for Evaluating Alternative Courses of Action for Tactical Engagement

by

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This technical report describes a decision-aiding technique developed to assist division-level commanders and their staffs in choosing among alternative courses of action for tactical engagement. By employing principles of multi-attribute utility assessment methodology, a two-level model consisting of five general categories (terrain, own forces, enemy forces, weather, and risk) and twenty-four factors was developed and implemented on an IBM 5100 computer. In applying the decision aid, the

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) user is required to score each of the alternative courses of action on each factor and to assign a weight indicating the importance of each factor in discriminating among the alternatives. A simple algorithm is used to calculate a weighted score for each course of action, the highest score being an indication of the preferred course of action. A sensitivity analysis provides a measure of the robustness of the scores and weights assigned by the user.

The aid was designed to provide:

1. A checklist of the salient factors that need to be considered in choosing among alternative courses of action, thus at least inviting detailed consideration of the complete spectrum of factors that bear on tactical choice.

2. A logical method for integrating subjective elemental assessments into an indication of choice. To the extent that the elemental (factor) judgments are valid, the preferred course of action thus derived should be the optimal choice given the way the decision maker has valued courses of action on the various factors.

3. A means of well-focused communication about the decision problem at hand, by making the decision problem and value structure explicit and by requiring judgments in quantitative rather than qualitative terms.

SUMMARY

This technical report describes a decision-aiding technique developed to assist division-level commanders and their staffs in choosing among alternative courses of action for tactical engagement. By employing principles of multi-attribute utility assessment methodology, a two-level model consisting of five general categories (terrain, own forces, enemy forces, weather, and risk) and twenty-four factors was developed and implemented on an IBM 5100 computer. In applying the decision aid, the user is required to score each of the alternative courses of action on each factor and to assign a weight indicating the importance of each factor in discriminating among the alternatives. A simple algorithm is used to calculate a weighted score for each course of action, the highest score being an indication of the preferred course of action. A sensitivity analysis provides a measure of the robustness of the scores and weights assigned by the user.

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Since all training is basically concerned with shaping the trainee's internal value structure, the property of the decision aid in making that subjective structure visible in detail should be of value in training contexts concerned with tactical decision making.

FOREWORD

The Human Factors Technical Area of the Army Research Institute is concerned with the human resource demands of increasingly complex battlefield systems used to acquire, transmit, process, disseminate, and utilize information. This increased complexity places great demands upon the operator interacting with the machine system. Current research focuses on human performance problems related to interactions within command and control centers, as well as on issues of system development. It is concerned with such areas as software development, topographic products and procedures, tactical symbology, user-oriented systems, decision making, systems integration, and utilization.

An area of special interest is the exploitation of tactical data systems to assist the tactical commander and staff in analysis and decision making. One approach, used in the current effort, is to adapt the formal methods of decision analysis to the tactical decision process. A decision support module was developed to assist users in evaluating alternative friendly courses of action. A preliminary evaluation conducted at Fort Leavenworth, Kansas, was extremely favorable, and recommendations were made for field and classroom implementation.

Research in the area of decision support is conducted as an in-house effort augmented contractually by organizations selected for their unique capabilities and facilities for research in this area. This effort is responsive to the requirements of Army Project 2Q762722A765, as well as to the general requirements of HRN 77-296 (ADP Methods for Utilization of Analytic Aids and Logic Models in Intelligence Processing) and HRN 78-151 (Processing and Problem Solving Aids in Tactical Systems).

CONTENTS

FIGURES

1.0 INTRODUCTION

Technological advances in weaponry and associated support systems have greatly increased the complex of factors which must be taken into account in tactical decision making. While decision acumen has long been of paramount importance in combat, in modern warfare the speed with which forces can be committed to action and the enormous lethality of arms have created a circumstance where disaster, rather than increased losses or a temporary setback, is a much more likely consequence of poor tactical decisions. These factors, along with compelling research evidence (References 3, 5, 12, 14) pointing to profound human fallibilities in even simple decision tasks, have served as the impetus for a search for ways to aid commanders and their staffs in the extremely complex, high-stake decision situations they face.

Evaluating and choosing among alternative courses of action in tactical situations is an example of what is often an extremely complex, difficult, and critical decision task, and one that is the central focus of the decision-aid development described in this report. As presently conducted, the assessment of alternative courses of action requires that the commander hold in mind the essential details of friendly action options, those of the enemy, along with a host of factors bearing on the effectiveness of each, while conducting a mental war-game of the action and results that would ensue from each option. The course of action deemed most appropriate in this rather global thought process becomes the selected option.

While skilled decision makers do a remarkably good job in these judgmental decision roles, considering their complexity, experimental evidence demonstrates that in probabilistic, multi-attributed decision tasks such as these, many fallibilities of judgment often come into play. Relevant attributes may be overlooked, probabilistic inferences may be faulty, and the integration of information over many relevant decision dimensions may not be logically consistent with either the objective situation or the decision maker's subjective evaluation of the objective information.

Decision analysis, an applied derivative of statistical decision theory, is a methodology developed to help decision makers avoid these judgmental pitfalls and to aid them in reaching logically consistent, rational choices. The methodology is fully described in a number of sources (References 4, 7, 8, 11, 13). In brief, it represents a divide-and-conquer approach: Complex decision problems are disaggregated into the relevant component or elemental factors; judgments (valuations) are rendered by the decision maker on these elemental factors (which presumably are cognitively easier for the decision maker); these elemental valuations are then aggregated via formal, logical algorithms into an indication of optimal choice.

In the decision aid development described in this paper, one aspect of decision analysis, multi-attribute utility assessment (MAUA), was used as the methodological base. This method is summarized and fully treated in References 6 and 7. In brief, MAUA is a method for deriving a single index of worth for an object of assessment having multiple and often conflicting dimensions of value. Possible courses of action for an impending military engagement are examples of such multi-attributed alternatives. One course of action, for example, might be superior in terms of avenue of approach, and the degree to which it exploits fields of fire, but may be poor in terms of, say, mobility and logistic support provisions. It is often the case, as in the example just given, that the many relevant attributes have no objective metric; and it is usually the case that a common metric applicable to each of the relevant attributes is lacking.

In the MAUA approach, this measurement problem is handled by the concept of subjective utility--an expression of subjective value. In applying MAUA, the objects of assessment (in this case, alternative courses of action for tactical engagement) are disaggregated into their relevant major attributes (factors). An expression of the decision maker's utility for the contributions of each of the attributes to overall performance is elicited. These utilities are then aggregated by appropriate algorithms to yield an overall index of worth (utility) for each of the options under consideration. Thus, MAUA is a means of systematically and logically combining subjective assessments into overall indices of worth.

It should be pointed out that all decisions are matters of subjective judgment. Even with perfect information, the critical interplay between information and the subjective, internal value structure of the decision maker is the true locus of decision. The MAUA approach makes those subjective assessments explicit attribute-by-attribute and provides a formal logic for aggregating the elemental judgments into an indication for choice. The use of subjective judgments in MAUA is in no way a substitute for hard objective data. Rather, the approach captures, in a systematic fashion, the judgmental implications of whatever relevant information is at hand.

2.0 THE DECISION PROBLEM

The decision aid development effort covered in this report focused specifically on the problem of choosing the best course of action from a set of alternative courses of action for tactical engagement. The focus was further constrained to division-level operations, though the decision-aiding model that was developed is probably appropriate to other command echelons as well.

As taught in the Army Command and General Staff College, the decision process for evaluating and choosing among alternative courses of action entails the following steps (Reference 1):

1. Given a corps order assigning a mission, identify specified and implied tasks.

2. Restate the mission as necessary to ensure understanding.

3. Gather and analyze all relevant data.

4. Make logical assumptions in areas where data is unavailable.

5. Conduct mini-analyses of the situation and mission and formulate alternative courses of action.

6. Assess the alternative courses of action by war-gaming each through the impending action and choose that which fares best.

A number of general points should be made with regard to the six steps presented above. First, it is recognized that the steps are an approximation to a formal school model. In field applications, one is certain to find many variants of and alternatives to the six-step decision process. These will be driven largely by the commander's "style" and the time available to make a choice. Nonetheless, however approached, the intricate array of factors that must be considered in reaching a choice make a formidable decision task indeed. Secondly, while all the steps outlined above are important, steps five and six, concerned with the formulation of courses of action and the assessment of them, are steps that entail the level of decision complexity that often leads to less than optimal choices. We will have little to say about the crucial step of formulating courses of action beyond noting in passing that this complex step bears very heavily on the quality of the choice that will eventually be made. If a "best" option is not formulated as a candidate for selection, it obviously cannot be selected by any methodology. Our attention focused solely on assessing and choosing among alternative courses of action once these were formulated. In this endeavor, we assumed that the alternatives posed were all serious contenders when initially formulated rather than a lead candidate with weak alternatives thrown in for exercise purposes. In the latter case, decision aiding would hardly be required.

Turning attention now to the sixth step, war-gaming the alternative courses of action to select the best one, consider the information burden and mental integration involved. The decision maker must hold in mind all potential friendly courses of action, as well as those open to the enemy; in addition, there are a host of factors bearing on the execution of all of these possible actions. With all this held in mind, the decision maker (commander) plays out a mental war-game, testing each course of action to reach a decision as to which is best. Even if one invokes concepts of "chunking" and other methods involving substitution of concepts for detail, it should be evident that the required decision can be an extremely complex and difficult matter. Research strongly supports the view that if people must contend with more than five to seven factors simultaneously, sometimes judgment degrades. Relevant factors may be overlooked; recent information is often afforded inordinately higher value than earlier but still relevant information. It is also the case that with multiple factors exceeding five to seven (or less) mental integration of values can be faulty. These and other judgmental fallibilities can lead to decisions that are often not consistent with either objective information or the way that information is valued by the decision makers (References 3, 5, 12, 14). However, it should be noted that under some circumstances, highly trained judges can indeed make accurate judgments integrating upwards of ten factors (Reference 10).

The multi-attribute utility assessment methodology used as the basis for the decision aid development was evolved to minimize these judgmental fallibilities in complex decision tasks. The method involves two basic principles: 1) disaggregate the decision problem into its relevant attributes (factors), each of which should be more within the cognitive range of the decision maker than the "wholistic" judgment otherwise required; and 2) allocate to a computer the task of logically integrating the elemental judgments of the decision maker into an implied choice.

3.1 Criteria and Model Structure

The first step in developing an aid for the decision context under consideration was to define an appropriate problem structure. In doing this, we were guided by the following criteria:

1. The elemental judgments required (dictated by the problem structure) had to be sufficiently few in number to require no more than one hour to complete.

2. The required judgments had to be meaningful to people knowledgeable about division-level tactical operations.

3. The structure had to be devised to avoid redundancies among factors (to avoid redundant weightings in the aggregation of weighted scores).

4. The structure of the model was intended to ensure general applicability to a wide range of tactical operations, both offensive and defensive.

Unfortunately, there is no set of rules to guide the process of decision-problem structuring. It is, quite frankly, an iterative, cut-and-try process.

To identify the array of factors that influence tactical choice, relevant Army manuals were reviewed, and consultations were held with combat-experienced, division-level commanders, as well as with members of the faculty of the Army Command and General Staff College at Fort Leavenworth.

From the array of relevant factors garnered from these sources, preliminary factor structures were generated and evaluated by personnel experienced in the tactical decision role at issue. Through a series of iterations, the decision model presented in Figure 1 was evolved as a suitable representation. Figure 2 shows a detailed delineation of the twenty-four factors contained in the model in exactly the form they are posed for judgment elicitation purposes.

3.2 Operation of the Decision Aid

There are four basic steps required of the decision maker in using the prototype decision aid.

1. For each of the factors shown in Figure 2 the decision maker is required to assign scores to each of the courses of action, designating which is best in terms of the factor under consideration, which is worst, and, if there are more than two courses of action, where each of the remaining courses of action would fall on a scale relative to the poorest and best options. Rules that must be adhered to in scoring courses of action are presented in Figure 3.

2. The second step in exercising the decision aid requires the decision maker to judge for each factor the importance of the difference between the course of action scored poorest and best and to rank-order the factors in terms of these difference judgments. This is a convenience step and is not a computational necessity. The rank-ordering step is intended to make the assignment of importance weights, as required in the next step, more orderly and reliable.

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[1] Descriptions of earlier versions of the model are available from Army Research Institute, 5001 Eisenhower Avenue, PERI-OS, Alexandria, VA 22333.

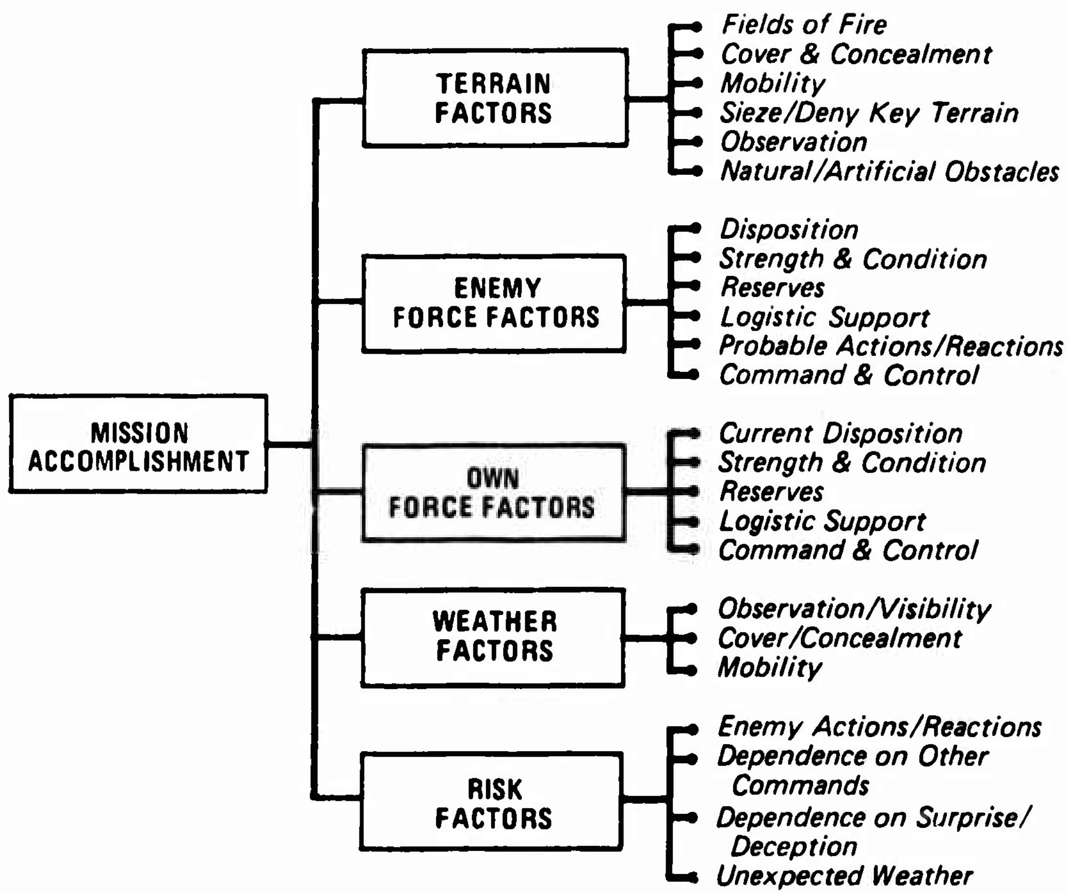

Figure 1. **STRUCTURE OF DECISION-AIDING MODEL**

ARMY EVAL V

Factor Listing

I. Terrain Factors

As related to mission accomplishment, score each of your courses of action in terms of how well each:

1.1 Exploits field of fire afforded by terrain features

1.2 Exploits cover and concealment afforded by terrain features

1.3 Exploits mobility provisions due to terrain features

1.4 Accomplishes rapid seizure or denial of key terrain

1.5 Exploits observation provisions of terrain

1.6 Exploits or accommodates natural and artificial obstacles

II. Enemy Force Factors

As related to mission accomplishment, score each of your courses of action in terms of how well each exploits what you know or estimate about:

2.1 Enemy disposition

2.2 Enemy strength and condition

2.3 Enemy reserves

2.4 Enemy logistic support

2.5 Probably enemy actions/reactions

2.6 Enemy command and control capabilities/vulnerabilities

Figure 2. ARMY EVAL V
Factor Listing

III. Own Force Factors

As related to mission accomplishment, score each of your courses of action in terms of how well each exploits or accommodates:

3.1 Own force current disposition

3.2 Own force strength and condition

3.3 Own force reserves

3.4 Own logistic support

3.5 Own command and control capabilities/vulnerabilities

IV. Weather Factors

As related to mission accomplishment, score each of your courses of action in terms of how well each exploits:

4.1 Observation/visibility conditions forecast to exist due to weather

4.2 Cover and concealment conditions forecast to exist due to weather

4.3 Mobility conditions forecast to exist due to weather

V. Risk Factors

As related to mission accomplishment, score each of your courses of action in terms of:

5.1 Ability to cope with surprises in terms of enemy strength or enemy actions/reactions

5.2 Freedom from dependence on forces not under own control

5.3 Freedom from critical dependence on surprise or deception

5.4 Suitability under unexpected adverse weather conditions

Figure 2 (Con't)

- BEST CA* ON FACTOR = 100
- WORST CA ON FACTOR = 0
- INTERMEDIATE CA = RELATIVE SCORE
- ALL CAs SAME ON FACTOR = ASSIGN 0 TO ALL

- EXAMPLE

  AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF HOW WELL EACH:

  1.1 Exploits fields of fire afforded by terrain features

  CA 1 ______ CA 2 ______ CA 3 ______

*Course of Action

Figure 3. Scoring Rules

of the difference between the extreme courses of action on a factor. With practice, the correct frame of reference for judging importance weights becomes routine. Even then, however, there remains an uncertainty band around the importance weights entered into the model. The decision maker may have entered a weight of, say, 70 for a factor but was really uncertain as to whether that value might just as well have been 60 or 80. When such uncertainty enters the picture (as is usually the case), it is of great importance to know whether variation of the judgmental inputs within the decision maker's band of error would shift the indicated course of action selection from one option to another--a matter of sensitivity testing.

3.3 Sensitivity Analysis

A common approach to a sensitivity analysis, which involves testing how robust the ordering of courses of action would be when weights are varied within their tolerances, is to vary each weight individually, keeping the ratio of all the other weights fixed. The disadvantage of this approach is that some variation of several weights together may cause a change in the best course of action much sooner than if weights were varied separately.

To overcome this problem, a novel approach to sensitivity analysis in this kind of model has been incorporated in the prototype decision aid. Given any particular set of weights, a minimum change in those weights (moving in combination) is determined which would yield a different course of action with the highest weighted score. Some measure of what is meant by the size of a change in weights is necessary to carry this out; the measure adopted is the Euclidean distance, the sum of the squares of the difference of each weight from its starting position. It is recognized that this may not be the most appropriate measure in all circumstances. For example, if the user is far more confident with some weights than with others, it may make sense to consider a small change in a well-defined weight to be "equivalent" to a much larger change in another weight, suggesting that a weighted sum of squares may be a more appropriate measure. In this effort, however, issues of this kind are not pursued.

Once the minimum change in weights necessary to change the recommended course of action is determined (along with the changed weights), the decision maker can consider whether or not these changed weights are consistent with the intended judgments. If, as will generally be the case, the changed weights are not consistent, then the user can be confident that the numbers given, though rough, have a clear-cut implication. If, on the other hand, the new weights are consistent with the judgments, then it can be assumed the user is not discriminating between the two courses of action. At this point, judgments must be refined by further introspection and information gathering, or it must be recognized that there is no basis to prefer one course of action over its closest rival.

As implemented on the IBM 5100 computer, the sensitivity test is performed in a matter of seconds and is an indispensible part of the evaluation model. The formal algorithm underlying the sensitivity test is presented in Appendix A.

3.4 Computer Implementation

The model as described in the preceding sections was implemented in prototype form on an IBM 5100 portable computer. The computer-based model is designed for direct, on-

3. After considering again the importance of the difference between the courses of action scored poorest and best on each factor, the decision maker is next required to assign relative importance weights to each of the differences. Using as a reference a weight of 100 assigned to the most important difference, the decision maker must assign a relative weight to the second most important difference, the third most important, and so on, each weight reflecting the percentage worth of the difference under consideration to that judged most important and assigned a weight of 100. In making this judgment, the decision maker asks, "Relative to the top-ranked difference and its weight of 100, how much is the difference between the poorest and best course of action on the next-ranked factor worth to me, 80% as much? 50% as much?"--and so on.

The foregoing steps are accomplished in serial sets, first for the category concerned with terrain factors, then for enemy force factors, own force factors, weather factors, and risk factors.

4. After all the above scores and weights have been entered by the decision maker, the final judgmental operation required is to assign importance weights to each of the five categories. To accomplish this, a set of five factors consisting of the top-weighted factor from each category is presented. Again, the decision maker is required to judge the relative importance of the magnitude of the difference between the courses of action scored poorest and best on each of these factors and to rank and weight these differences just as before. This

operation has the effect of adjusting factor weights by the importance weighting of the category of which each is a part. If, for example, the three factors under weather had been assigned weights of 100, 80, and 30 on the basis of their relative importance within the weather category, and the weight then assigned the weather category was 50, the adjusted weights for the weather factors would become 50, 40, and 15.

The above scoring, ranking, and weighting steps encompass all of the judgmental inputs required of the decision maker. When these steps are completed, the computer into which the judgmental values were entered automatically calculates weighted scores for each of the courses of action under assessment. This calculation is simple arithmetic involving summing over all factors for each course of action the product of the normalized factor weight times the normalized category weight, times the factor score assigned each course of action. Assuming that the scores and weights are valid and that the model captures the salient factors relevant to the decision, the course of action yielding the highest weighted score should be the preferred option.

It is worth noting at this point that while the process of assigning scores to courses of action (i.e., specifying the one which is best on a factor, worst, and intermediate) is found to be an easy task by most decision makers, the process of assigning importance weights to magnitudes of difference is initially an unfamiliar way of thinking for most. Unless users of the decision aid are carefully briefed and prompted in early trials, there is a tendency for many to slip into the conventional (but, in this context, erroneous) pattern of assigning weights to the perceived importance of a factor generally, rather than to the importance line use by a decision maker. The necessary instructions in the dynamics of the model and the judgments required are programmed for computer presentation (Appendix B presents a complete printed version of the instructions and factor structure). The program systematically presents the factors (as shown in Figure 2 and Appendix B) and elicits the required judgmental inputs (which the user enters into the machine by means of simple keyboard operations). When the judgmental sequence is completed over all twenty-four factors, the computer automatically calculates and displays weighted scores for each course of action based on the judgments provided by the user. A sample printout showing the summary results of one application of the model is presented in Figure 4.

The computer model, in its present form, also has provision for a number of analytic and convenience options that should prove useful to a decision maker. By a simple operation of positioning a cursor under the desired option presented in an option menu (see Figure 5), the user can exercise any of the following analytical features:

1. Display Results: Selection of this option presents a visual display of summary results which includes cumulative weighted scores for each course of action within each of the five categories, total weighted score for each course of action, relative weights assigned each category, and the percentage of the total weight assigned each category.

2. Sensitivity Test: Selection of this option causes execution of the sensitivity test routine as described in Section 3.3 and Appendix A. A sample printout showing the substance and format of a sensitivity test is shown in Figure 6.

```
1. MISSION ACCOMPLISHMENT
    FACTOR          WT CA1 CA2 CA3    CUMWT
 1) TERRAIN
                  ( 95)  8  18  15    23.19%
 2) ENEMY FORCES
                  ( 70)  0  12  17    17.09%
 3) OWN FORCES
                  (100) 31  43  14    50.45%
 4) WEATHER
                  ( 30)  5   7   4     9.28%
 5) RISK FACTORS
                  (  0)  0   0   0      .00%
    TOTAL               44  79  51   100.00%
```

a. Numbers in parentheses indicate the weight assigned each category.

b. Numbers under CA1, CA2, CA3 (courses of action) are cumulative weighted scores over all factors within each category.

c. The column headed "CUMWT" shows the normalized weights assigned each category.

Figure 4. Sample Printout Showing Format and Content of Decision Model Results Calculation

```
SELECT ANY SINGLE OPTION BY TYPING A CHARACTER UNDER ITS POINTER

 ┌──DISPLAY RESULTS
 |     ┌──SENSITIVITY
 |     |     ┌──EDIT VALUES
 |     |     |     ┌──PRINT RESULTS
 |     |     |     |     ┌──RANK RESULTS
 |     |     |     |     |     ┌──LOAD MODEL
 |     |     |     |     |     |     ┌──SAVE MODEL
 |     |     |     |     |     |     |     ┌──NEW VALUES
_|_   _|_   _|_   _|_   _|_   _|_   _|_   _|_
                              R
```

Figure 5. Sample Printout of the Menu of Analytic Options Available in the Computer-Based Decision Aid

1. MISSION ACCOMPLISHMENT
 1) TERRAIN
 2) ENEMY FORCES
 3) OWN FORCES
 4) WEATHER
 5) RISK FACTORS

FACTOR	(1)	(2)	(3)	(4)	(5)	TOTAL	BEST CA
CUR CUMWTS	23.19	17.09	50.45	9.28	.00	100.00	CA2
EQL CUMWTS	30 16	39.22	3.14	15.80	11.69	100.00	CA3

a. The numbers in the row opposite "FACTOR" represent the category titles listed immediately above that row: (1) terrain, (2) enemy forces, etc.

b. "CUR CUMWTS" shows the normalized weight assigned each category.

c. "EQL CUMWTS" shows the normalized weight that would have to be assigned each category in combination to shift the indication of preferred choice (best CA) to the next closest option.

Figure 6. Sample Printout Showing Format and Content of the Sensitivity Test Calculation

3. Edit Values: Selection of this option allows a user to return to any designated point in the model to change values and to recompute results based on the new values. Either scores or weights may be changed as specified by the user.

4. Print Results: Selection of this option causes creation of a comprehensive printout of the complete model, including scores, weights, and summary results.

5. Rank Results: Selection of this option results in the generation of complete factor listing in descending rank-order by the weight assigned each factor.

6. Load Model: Selection of this option causes the display of titles to all models stored on the program cassette and further enables the user to designate any one of those models for loading into the computer for further reference and analysis.

7. Save Model: Selection of this option enables a user, upon completion of a model, to store the model on the program cassette for further reference. Models thus saved are recoverable via the "Load Model" option described in 6, above.

8. New Values: Selection of this option calls into play the basic, unvalued elicitation form of the model.

4.0 EVALUATION OF THE PROTOTYPE AID

An informal evaluation of the decision aid was conducted to screen out any gross errors in structure, wording, or instructions and to obtain general user reactions from Army officers. The goal of this evaluation was to identify any obviously necessary changes in preparation for a more formal preliminary evaluation at Fort Leavenworth.

Trial runs of the decision-aiding model were conducted by using five Army Officers (grades 0-4 and 0-5) as participants. The decision context involved choosing among alternative courses of action in two separate scenario-based exercises used for training purposes by the Army Command and General Staff College, Fort Leavenworth. One of the exercises was a defensive scenario (Jayhawk, lesson plan P-113); the other involved an offensive scenario (Bonerland, lesson plan P-111). For purposes of gaining some insight into the reliability of the judgmental inputs to the model, each of the officers conducted the same decision exercise twice in immediate succession.

Observations and comments are summarized below:

1. Users required about one hour to complete the procedure on their first exposure, but only about 35 minutes on their second. The need for less time can be attributed to an increased familiarity with the scenario materials as well as the aid procedures and operations. A practiced user would probably require no more than 15 minutes.

2. Assigning scores to the courses of action caused users little difficulty. However, users did have difficulty understanding and applying the weighting

rules. The main problem seemed to be that the participants were unable to consider the importance of a factor as a <u>discriminator</u> among courses of action. However, in spite of this difficulty, the variability in weights assigned was never great enough to cause a change in the rank order of the courses of action.

3. No participants recommended deletion or addition of factors.

4. All participants agreed that the aiding procedure helps them to understand their own judgment structure and would be a valuable training device. While one felt the aid was too tedious, the other four felt that it would be useful as an adjunct field decision aid.

A more elaborate evaluation involving eleven officers was conducted at Fort Leavenworth. In general, the results substantiated those listed above. While there were no recommendations for the modification, addition, or deletion of factors, two problem areas in the use of the aid were identified. First, while users had little difficulty understanding the concept of assigning value scores to the courses of action, some users were not consistent when making repetitive judgments. Second, there was considerable difficulty in applying the weighting rules requiring the assessment of the factor as a discriminator among the courses of action. However, these problems were largely overcome with increased practice and instruction. All participants felt the aid would be beneficial to either a field operating command staff or students training in tactical decision making. Details and discussion of the evaluation are available in Appendix C.

In terms of continued evaluation and implementation of the aid, the evaluation indicated two promising approaches. One would be to incorporate the aid into an ongoing tactical simulation in which a commander and staff could actually use the aid in making their decisions. A second approach involves using the aid as a training device in teaching tactical decision making. Students could work through the aid and compare their input values and weights, as well as solutions, with the instructor's. This would be helpful not only in identifying errors but also by providing a focus for discussing factors on which there is disagreement. Based on the present evaluation, the structure and format of the aid seem quite adequate. Directions for any further modifications will appear only after the aid has been implemented and used in either a classroom or tactical decision-making context.

However, even without any modifications, the aid should provide a future user with:

1. A checklist of the salient factors that need to be considered in choosing among alternative courses of action, thus at least inviting detailed consideration of the complete spectrum of factors that bear on tactical choice.

2. A logical method for integrating subjective elemental assessments into an indication of choice. To the extent that the elemental (factor) judgments are valid, the preferred course of action thus derived should be the optimal choice given the way the decision maker has valued courses of action on the various factors.

3. A means of well-focused communication about the decision problem at hand, by making the decision problem and value structure explicit and requiring

specification of judgments in quantitative rather than qualitative terms. As a concise summary of how alternative courses of action are valued, there is opportunity for rapid staff review and specific corrective or amplifying input as may be required. Specific areas of disagreement or misunderstanding are readily identifiable, and one can rapidly test for the impact on the decision of new values that may be proposed.

Since all training is basically concerned with shaping the trainee's internal value structure, the property of the decision aid in making that subjective structure visible in detail should be of value in training contexts concerned with tactical decision making. Knowing not only what choice a student would make, but also factor-by-factor "why and how much" may well reveal some astounding misperceptions that would otherwise go undetected and, hence, remain uncorrected. Further, in a training context, prior experience with other decision aids similar in method has supported the view that the structured decision model makes an excellent classroom tool for group interaction on a decision problem. Working to collectively agree on values to enter into the model promotes lively discussion that is both interesting and of apparently high instructional value.

APPENDIX A
SENSITIVITY ANALYSIS ALGORITHM

In this Appendix, a mathematical account of the algorithm to carry out the sensitivity test is described. If there are n attributes and m courses of action, the evaluation procedure calculates

$$\overline{b}_i = \sum_{j=1}^{n} w_j b_{ij}$$

for each course of action i. Here $(w_1, \ldots, w_n)$ are the weights and $(b_{i1}, \ldots, b_{in})$ are the scores for course of action i. The best course of action is the one with the highest weighted score $\overline{b}_i$.

The problem to be solved in performing the sensitivity test described above can be stated as follows. Let $\{\mathring{w}_j\}$ be the weights initially elicited; suppose with these weights, course of action p is best. Then the problem is to determine $\underline{w}$ such that

$$\sum_{j=1}^{n} (w_j - \mathring{w}_j)^2$$

is minimized, subject to the constraints

$$\sum_{j=1}^{n} w_j b_{ij} \leq \sum_{j=1}^{n} w_j b_{pj}, \text{ all } i \neq p,$$

$$\sum_{j=1}^{n} w_j = 100, \text{ and } 0 \leq w_j < 100, \text{ all } j.$$

This will find the nearest point in $\underline{w}$-space to $\underline{\mathring{w}}$, such that course of action p is equivalent to some other course of action.

Although the problem as formulated is a quadratic program, and can, therefore, be solved by using a quadratic programming algorithm, there is a more efficient algorithm which employs the special structure of the problem, and this has been used here.

It is convenient to talk of regions of the feasible part of $\underline{w}$-space in which each option has best weighted score. "Region i" is the part of $\underline{w}$-space in which $\bar{\underline{b}}_i \geq \bar{\underline{b}}_j$, for all $j \neq i$. The problem consists of finding the point on the boundary of region p which is nearest to $\overset{o}{\underline{w}}$. Note first that if the perpendicular distance from $\overset{o}{\underline{w}}$ to the hyperplane on which $\bar{\underline{b}}_q = \bar{\underline{b}}_p$, for some other option q, is in fact on the boundary of region p, then that perpendicular distance is a contender for the minimum distance before change occurs.

The following algorithm emerges:

1. For each $i \neq p$, calculate the perpendicular projection of $\overset{o}{\underline{w}}$ onto the hyperplane $\sum_{i=1}^{n} w_i (b_{ij} - b_{pj}) = 0$ subject to the constraint $\sum_{i=1}^{n} w_i = 100$.

   This is given by the expression:

$$w_i = \overset{o}{w}_i - \frac{nC}{nB - A^2} b_{pi} + \frac{AC}{nB - A^2}$$

   where $A = \sum_{j=1}^{n} b_{pj}$, $B = \sum_{j=1}^{n} b_{pj}^2$, $C = \sum_{j=1}^{n} \overset{o}{w}_j b_{pj}$

2. Check to see if the point so calculated satisfies $w_i \geq 0$, for all i; if not, construct a new problem by omitting all components of each vector corresponding to indices for which $w_i < 0$, and recalculate a similar expression to the one above (with new definitions of n, A, B, C, and subject this time to the constraint

$$\sum_{i=1}^{n} w_i = \sum_{i=1}^{n} \overset{o}{w}_i).$$

   Iterating this procedure (several times if necessary) will produce a reduced vector all of whose elements are non-negative. A vector in $\underline{w}$-space is now created by inserting zeroes for all components which have been excluded by this procedure.

The vector created by this method is the nearest point from $\underset{\sim}{\mathring{w}}$ to the hyperplane $\underline{E}_i = \underline{E}_p$. Let us call it $\underline{\mathring{w}}_i$.

3. Now check to determine if $\underline{\mathring{w}}_i$ is "covered" in the sense that there is some $j \neq i$ or p such that

$$\sum_{k=1}^{n} \mathring{w}_{ik}\, b_{jk} > \sum_{k=1}^{n} \mathring{w}_{ik}\, b_{ik}.$$

If this is the case, the nearest point to $\underline{\mathring{w}}$ is not in region i, and this possibility can be excluded.

4. For all non-excluded $i (\neq p)$, calculate the distance from $\underline{\mathring{w}}$ to $\underline{\mathring{w}}_{ij}$. The smallest of these indicates where the minimum change occurs, and it is this vector which represents the smallest change in weights necessary to change the preferred option.

This algorithm is implemented on the software constructed for the IBM 5100 to explore the sensitivity of judgments made in the evaluation procedure.

APPENDIX B

ARMY EVAL V: MANUAL VERSION[1]

This procedure is designed to assist you in evaluating the different courses of action you have formulated as part of the process of developing the Commander's Estimate. In formulating your courses of action, it is assumed that the following important steps have been accomplished:

A. specified tasks identified;

B. implied tasks identified;

C. bounds of action established and communicated;

D. all data relevant to mission/action is identified and analyzed; and

E. logical assumptions made where data is missing.

With the above steps completed and your alternative courses of action formulated, you are ready to compare the courses of action in terms of the many factors bearing on

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[1] This manual version of the decision aid was prepared to expedite testing of the aiding concept (multiple users could be run simultaneously). The version presented here is identical to the computer-based version with the following exceptions:

a. Values were entered via the computer keyboard in the computerized model and manually noted in the manual version.

b. The computerized model automatically displayed instructions and the factor listing (serially).

c. The computer version, of course, had the computation power described in Section 3.4. There was no on-line computation capability in the manual version.

them in order to reach a decision as to which is best. This procedure is designed to help you make the necessary comparisons and reach a logical decision.

The procedure works by asking you first to score your courses of action against each of a series of factors identified as being relevant to mission success. After you have scored your courses of action, you will then be asked to rate (weight) the relative importance of the differences between courses of action for each factor. Based on the scores and ratings (weights) you assign, an overall weighted-value index for each course of action can be calculated.

It is important to understand that this procedure is not making a decision for you. All the judgments used are yours. The procedure, in this case, serves as a reminder of the array of relevant factors to be considered and provides a way to calculate a logical conclusion based on your own judgments.

We will now proceed with the evaluation.

RULES FOR SCORING

The first step will be to assign scores to each of your courses of action for each of a series of factors bearing on mission accomplishment. The following rules must be adhered to in scoring your courses of action:

1. For each factor, decide which course of action is best with respect to that factor and assign a score of 100 to that course of action. If two or more courses of action are tied as best, assign a score of 100 to each of them.

2. For each factor, decide which course of action is worst with respect to that factor and assign a score of zero to that course of action. If two or more courses of action are tied as the worst for that factor, assign a score of zero to each of them.

3. With best and worst identified as in Steps 1 and 2 above, assign relative scores to each of the remaining courses of action. These scores should reflect where you feel each course of action would fall on the scale between zero and 100.

4. If all courses of action are equally good or poor in terms of the factor under consideration, assign a score of zero to each of them.

With these rules in mind, you should now score your courses of action with respect to terrain factors.

[Next page]

1. TERRAIN FACTORS

AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF HOW WELL EACH:

1.1 exploits fields of fire afforded by terrain features

1.2 exploits cover and concealment afforded by terrain features

1.3 exploits mobility provisions due to terrain features

1.4 accomplishes rapid seizure or denial of key terrain

1.5 exploits observation provisions of terrain

1.6 exploits or accommodates natural and artificial obstacles

Scoring Rules

Best CA on factor = 100
Worst CA on factor = 0
Intermediate CA's = relative score values
Ties = assign same score

FACTOR WEIGHTINGS

It is now necessary to assign weights to each of the factors against which you have scored your courses of action. The weights you assign to each factor should show how much the difference between the poorest and best course of action for that factor really matters in terms of mission accomplishment. Some differences between courses of action may be large, but of little importance. Others may be small, but highly important. In assigning weights, you are to judge how important the improvement is between the poorest and best course of action for each factor.

Your first step is to rank-order the factor sheets in terms of the importance of the difference between the best and worst courses of action shown for each factor. Scan the factor sheets and ask yourself, "How much does the difference between the best and worst course of action shown on the sheet for each factor really matter?" Arrange the sheets from top to bottom in descending order of importance. The factor that you judge to be the most important differentiating factor should be on top.

The next step is to assign weights to each factor. To do this, consider the topmost factor--the one you ranked number 1 in terms of how much the difference between the poorest and best course of action would matter. Enter a weight of 100 in the "(Weight _____)" space on that sheet.[1] With that as a reference, consider the factor you ranked as

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[1] In the manual version used for pilot testing, the factor items (1.1, 1.2, etc.) shown on the preceeding page were each contained on a separate sheet of paper with spaces provided for entering scores and weights. Here, for ease of exposition, the factors have been consolidated as on the preceding page.

second most important. Ask yourself, "Relative to the most important factor and its weight of 100, how much is the difference between the poorest and best course of action for the second factor worth? Does that difference matter only half as much? Ten percent as much? Ninety percent as much?--and so on. When you decide on its percentage worth relative to the first one, assign that weight; that is, if you think it is 80 percent as important as the first difference, enter a weight of 80, and so on. Use the same thought process to assign weights to all the factors. Remember, you are weighting how much the difference between best and worst courses of action for each factor matters in terms of mission accomplishment--not simply how important a factor might be generally, or how big a difference there might be between cours s of action for a given factor. If, in your judgment, some of the factor differences are equally important, assign the same weights to those tied factors.

When you have assigned all the weights, set the factor sheets aside (still in descending order of importance) and turn to the next page. There you will be asked to repeat this process for <u>Enemy Force Factors</u>.

2. ENEMY FORCE FACTORS

AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF HOW WELL EACH EXPLOITS WHAT YOU KNOW OR ESTIMATE ABOUT:

2.1 enemy disposition

2.2 enemy strength and condition

2.3 enemy reserves

2.4 enemy logistic support

2.5 probably enemy actions/reactions

2.6 enemy command and control capabilities/ vulnerabilities

Scoring Rules

Best CA on factor = 100
Worst CA on factor = 0
Intermediate CA's = relative score values
Ties = assign same score

3. OWN FORCE FACTORS

AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF HOW WELL EACH EXPLOITS OR ACCOMMODATES:

3.1 own force current disposition

3.2 own force strength and condition

3.3 own force reserves

3.4 own logistic support

3.5 own command and control capabilities/ vulnerabilities

<u>Scoring Rules</u>

Best CA on factor = 100
Worst CA on factor = 0
Intermediate CA's = relative score values
Ties = assign same score

4. WEATHER FACTORS

AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF HOW WELL EACH EXPLOITS:

4.1 observation/visibility conditions forecast to exist due to weather

4.2 cover and concealment conditions forecast to exist due to weather

4.3 mobility conditions forecast to exist due to weather

<u>Scoring Rules</u>

Best CA on factor = 100
Worst CA on factor = 0
Intermediate CA's = relative score values
Ties = assign same score

5. RISK FACTORS

AS RELATED TO MISSION ACCOMPLISHMENT, SCORE EACH OF YOUR COURSES OF ACTION IN TERMS OF:

5.1 ability to cope with surprises in terms of enemy strength or enemy actions/reactions

5.2 freedom from dependence on forces not under your control

5.3 freedom from critical dependence on surprise or deception

5.4 suitability under unexpected adverse weather conditions

<u>Scoring Rules</u>

Best CA on factor = 100
Worst CA on factor = 0
Intermediate CA's = relative score values
Ties = assign same score

WEIGHT ADJUSTMENT

You have now scored your courses of action against all the factors and weighted those factors in terms of how important they are in differentiating between courses of action. As a final step, it will be necessary to determine adjusted weights for all factors. To do this, pick up the top-ranked factor sheet from each of the five factor sheet piles. Make certain that each sheet is in fact the one you designated as most important in its category. Now, with these five factor sheets[1] in hand, rank-order them in descending order of importance just as you did before. Then enter a weight of 100 in the "Adjusted Weight ____" space on the topmost factor sheet. Review the second ranked factor sheet in your hand and ask yourself, "Relative to the most important factor and its weight of 100, how much is the difference between the poorest and best course of action for the second factor worth? Does that difference matter only half as much? Ten percent as much? Ninety percent as much?"--and so on. When you decide on its percentage worth relative to the first one, assign that weight; that is, if you think it is 80 percent as important as the first difference, assign a weight of 80 and so on. Use the same thought process to assign weights to all the factors in the collection of the five best factors you are now considering. Remember, you are weighting how much the difference between best and worst courses of action for each factor matters in terms of mission accomplishments--not simply how important a factor might be

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[1]In the manual version used for pilot testing, the factor items (1.1, 1.2, etc.) shown on the preceding page were each contained on a separate sheet of paper with spaces provided for entering scores and weights. Here, for ease of exposition, the factors have been consolidated as on the preceding page.

generally, or how big a difference there might be between courses of action for a given factor. If, in your judgment, some of the factor differences are equally important, assign the same weights to those tied factors.

When you have assigned all the weights, we will calculate the cumulative weighted scores for your courses of action. The one with the highest value should be the preferred one for the mission under consideration.

APPENDIX C

AN EVALUATION OF THE PROTOTYPE DECISION AID BASED ON INPUT FROM POTENTIAL USERS[1]

A preliminary evaluation of the prototype tactical decision aid, described in detail in the main text, was conducted at Fort Leavenworth, Kansas. The evaluation focused on three issues: (1) the subjective reaction of potential users of the aid; (2) the impact of using the aid on decision making; and (3) the ability of users to systematically and reliably assign numerical values to their judgments of the factor values and weights.

Two potential uses of the decision aid are as a training device for students of tactical decision making and as an operational aid for the division command staff. To obtain input from individuals representing both of these areas, the evaluation was conducted at Fort Leavenworth, where the ARI Field Unit solicited participation from the Command and General Staff College (CGSC), Combined Arms Training Development Activity (CATRADA), and Combined Arms Combat Development Activity (CACDA). The evaluation was conducted 15-18 May 1978.

Method

Participants. Twelve individuals from CGSC, CACDA, and CATRADA each participated in a three-hour session. At the time of testing, the computer data for one individual was accidentally erased; thus, data were collected from only eleven individuals. The following biographical data was also collected:

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[1]This evaluation was conducted and prepared by Ruth H. Phelps of the Army Research Institute.

Age:	31-41 years
Years of Service:	12-24 years
Rank:	LTC-3; MAJ-6; CPT-2
Education:	BS-5; MA/MS-4; PhD/EdD-2; CGSC-8
Current Position:	CGSC-3; CACDA-4; CATRADA-3; Reserves-1.

Test Materials* and Design. The research design and test materials were developed to address the three issues listed above. The general approach to the evaluation involved the assessment of the participants' decision strategies before and after using the aid as well as the assessment of participants' ability to provide numerical inputs for the aid. The participants' decision task was to evaluate and rank order three courses of action in the context of a hypothetical scenario.

User reaction. All participants responded to a sixteen-item questionnaire concerning their opinions of the structure and phrases used to describe the factors contained in the aid, as well as the aid's potential usefulness in applications.

Impact of the aid. The effects on decision making of using the aid were assessed by comparing: (1) the accuracy and consistency of the participants' rank ordering of the three courses of action; and (2) the number and type of factors used before and after using the aid. In order to assess the accuracy and consistency of the rank ordering (1, above), participants listed their preferred rank ordering of the three courses of action both before and after using the aid.

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*Copies of test materials are available upon request from Army Research Institute, 5001 Eisenhower Avenue, Alexandria, Virginia 22333, ATTN: PERI-OS.

In order to obtain reasonably complete factor listings (2, above), participants completed two additional tasks. First, they simply listed from memory the "important factors." Second, participants sorted 24 cards, each listing a single factor, into four piles corresponding to the degree to which they used each factor when assessing the course of action. Factor lists generated in both tasks were obtained before and after using the decision aid the first time.

Assessment of numerical inputs. The validity of the feedback and numerical products of the aid depends on the quality of the numerical inputs provided by the user. To assess the ability of users to reliably and systematically assign numerical values to their judgments of factor values and weights, participants analyzed alternative courses of action for one of two different hypothetical scenarios. The scenarios were selected to provide diverse contexts in which to assess variations in the reliability of the judgments. Both scenarios were obtained from the CGSC and are currently used for classroom tactical instruction. The three alternative courses of action to be considered are described in detail by each scenario.

The Jayhawk scenario (Lesson Plan P-113) describes a defensive battle in detail by three maps and several reports, including enemy troop lists, weather data, order of battle data, corps analyses of area of operations, moon and solar data, intelligence reports, etc.

The Bonerland scenario (Lesson Plan P-111) is an offensive battle described by similar but considerably less detailed data.

To conserve the amount of time required to gather the data, two versions of the aid were used: computerized and manual. The structure and phrasing were identical for both; however, for the manual version responses were hand written and there was no capability for immediate feedback. By using two versions, two participants could work simultaneously.

Design. The assessment of User Reaction and Impact of the Aid were based on responses of all eleven participants. However, for the Assessment of Numerical Inputs, six participants only used the Jayhawk and four only used the Bonerland scenario. Half of the participants used the manual version first while the other half used the computer version first. Due to difficulties in scheduling, participants were not counterbalanced across scenarios.

Procedural Sequence. Each session lasted approximately three hours. The scenario material was available only during steps 2, 5, and 7 listed below.

1. Presentation of introductory material to both participants.

2. Individual study of scenario material.

3. Each participant describes decision strategy.

4. Presentation of decision procedures and instruction to both participants.

5. One participant uses computer while the other uses manual version.

6. Each participant describes decision strategy.

7. Participants switch aids so that each uses both versions.

8. Participants both answer User Reaction Questionnaire.

In order to complete the evaluation within the time constraints of most participants, Steps 3 and 6 were sometimes omitted. The precise number completing each section is stated in the Relevant Results section.

Results

User Reaction. All eleven participants completed the User Reaction Questionnaire.

Irrelevant factors. Seven participants indicated all 24 factors would be relevant for the evaluation of alternative courses of action. Only two recommended eliminating factors (#2.4, Enemy Logistic Support; #4.1, Observation/Visibility Conditions Due to Weather; #4.2, Cover and Concealment Conditions Due to Weather; #5.2, Freedom from Dependence on Independent Forces). Two other respondents felt some factors were redundant (#1.1, Fields of Fire Afforded by Terrain Features and #1.5, Observation Provision of Terrain; #2.1, Natural and Artificial Obstacles and #2.2, Enemy Disposition).

Additional and changes in factors. No respondents suggested additional factors be included. However, three felt that the phrasing of factors #5.2 (Freedom from Dependence on Independent Forces) and #5.3 (Freedom from Critical Dependence on Deception) was unclear. No other factors were listed as ambiguous.

Problems in assigning numerical values and weights. Five of the eleven respondents mentioned difficulties which could be generally categorized as a discomfort with the weighting rules; this should be alleviated with increased practice and instruction.

Benefits of using the aid. Seven of the eleven participants indicated they more critically evaluated the alternative courses of action when using the aid then in previous comparable decision situations when no aid was available. Similarly, ten indicated they considered more factors in their evaluation when using the aid. In addition, use of the aid relieved participants of the burden of remembering all factors simultaneously (9/11).

Applications of the aid. Although all participants indicated that decision aids are helpful and would use them in general, they felt this particular aid would be of most benefit in school-based training. The most frequently mentioned training benefit (9 respondents) was "to identify the factors on which student and instructor disagree and to focus classroom discussion in resolving the conflicts." Objections to using the aid in field operations centered on its complexity and, indirectly, on the amount of time required. In addition, five indicated the most valuable aspects of the aid were captured in the manual version (e.g., forces consideration of several factors, decomposes problems).

Impact of the Aid. Eight participants completed the following tasks:

Preferred rank orders. The preferred CGSC rank ordering of the three courses of action (school solution) was made available to ARI for each scenario. Three of the four participants using the Jayhawk scenario agreed with the school solution; however, three of the four using the Bonerland scenario disagreed with the school solution. Such differences may well reflect differing prior familiarity with the scenario since six had previously worked with Jayhawk in the classroom but only two had experience with Bonerland.

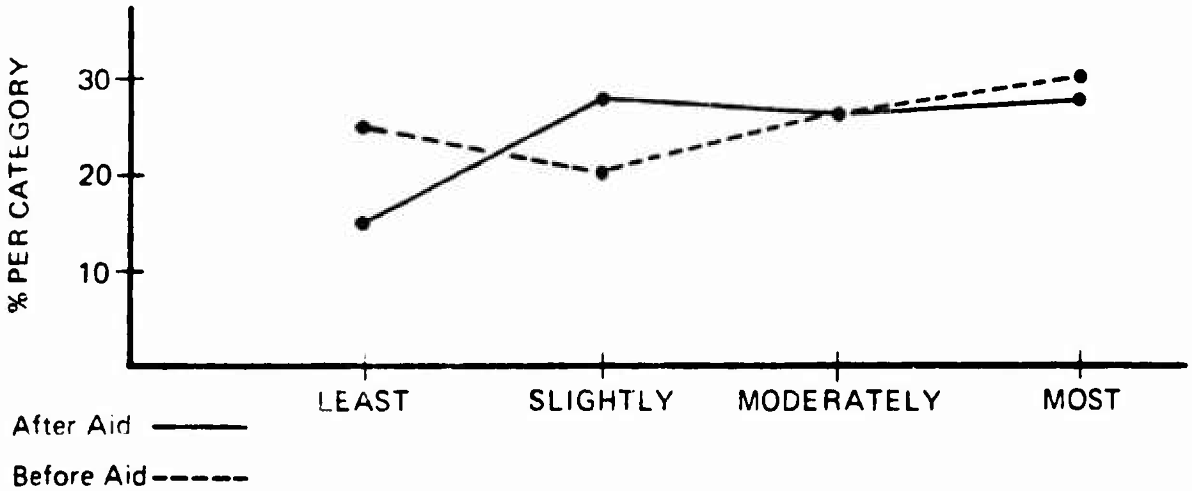
The respondents' rank orderings of the three courses of action was similar both before and after using an aid. Only one out of the eight switched a rank order; there was no difference in stability related to the scenario type.

Number of factors. Participants listed from memory the factors they had actually considered in making their evaluation of the three courses of action. The following table lists the total number of factors indicated and the number of factors which coincided with the 24 factors used in the aid, listed separately for two scenarios.

	Before Using Aid Aid Factors/Total	After Using Aid Aid Factors/Total
Jayhawk	8/10	25/27
Bonerland	8/21	16/22
Total	16/31	41/49

Clearly, the total number of factors listed increased after a single exposure to the aid. It appears that for the Jayhawk scenario, the post-aid increase is due to the addition of factors which were included in the aid. However, for the Bonerland scenario, the increase in the number of factors is small (from 21 to 22), but the number of aid factors doubled (from 8 to 16), indicating the number of non-aid factors was drastically reduced. Thus, it appears that the increase in the number of aid factors listed is a function of both the addition of aid factors and deletion of non-aid factors.

Participants also sorted the 24 factors into four categories corresponding to the degree to which that factor was used: Least, Slightly, Moderately, and Most Used. There were no differences between the scenarios. Below is a plot of the percentage of factors included in each category, for the two scenarios combined.



Clearly, there was no change in the number of factors in the Most and Moderate categories. The effect of the aid seems to be an increase in the Slightly Used and a corresponding decrease in the Least Used categories. Although the increase is small, it is impressive to see any change following a single exposure to an aid.

Assessment of Numerical Inputs. The degree of consistency between the numerical values assigned using the computer version and those assigned using the manual version was used as a measure of the reliability of the ratings for each participant. Discrepancies between the two sets of ratings indicate, at least at a gross level, the degree to which users can systematically provide the necessary numerical inputs.

Data were collected for both the manual and computer aids for ten participants (Jayhawk N=6; Bonerland N=4).

Calculated rank orders. The rank order calculated from the participants' input values was identical for most participants in both the manual and computer versions. For five of the six participants using Jayhawk and three of the four using Bonerland, analysis of their input values produced an identical rank ordering of the three alternative courses of action for the two aids.

Value scores. The values assigned to each course of action for the 24 factors were matched for the manual and computer aids for each participant. The degree of correspondence between the two was assessed by correlating the two sets of values and assessing the degree of discrepancy.

The average correlation between computer and manual scores is r=.63. The correspondence for those using Bonerland tends to be slightly higher (r=.71), than for those using Jayhawk (r=.56).

The discrepancies between the two versions can be categorized as: (1) reversal of extreme ranks (an order of 1-2-3 becomes 3-1-2 or 2-3-1 or 3-2-1) or (2) reversal of middle ranks (1-2-3 becomes 1-3-2 or 2-1-3). Clearly, reversal of extreme ranks represents a more severe discrepancy in values than changes in middle ranks. The following table lists the proportion of all responses in each category.

	Perfect Matching	Reversal of Middle Ranks	Reversal of Extreme Ranks
Jayhawk (N=6)	60%	34%	6%
Bonerland (N=4)	74%	19%	7%
Total (N=10)	65%	28%	6%

Weights. The relative weights assigned to the 24 factors for the manual aid were correlated with those for the computer version for each participant. Again, the average correlations for the Bonerland scenario group (r=.84) were higher than for the Jayhawk group (r=.72).

One of the major weighting rule errors committed by participants working with the Jayhawk scenario, but not those working with the Bonerland scenario, was the assignment of zeroes to a factor for all three courses of action, but a greater than zero weight to the factor. (By definition, if all three courses of action are scored as zero, the factor does not discriminate; thus, the weight should also be zero.) For the six Jayhawk participants, an average of 17% of the weights were in error. However, there is some indication these errors might be eliminated with practice, since the errors dropped from 22% on the first aid to 13% on the second aid, independent of whether the computer or manual version of the aid was used first.

Summary of scenario differences. Although participants working with the Bonerland scenario tended to disagree with the school solution, they were able to use the aids with greater consistency and fewer errors in their assignment of value scores and weights than those using the Jayhawk scenario. These differences are summarized on the following page:

	Bonerland	Jayhawk
Value Scores	r=.71	r=.56
Value Reversals	26%	40%
Weights	r=.84	r=.72
Weight Errors	0	17%
Agree w/School Solution	No	Yes

Discussion

The general reaction of all of the participants was quite positive. Although several had reservations about use of the aid by a tactical commander, most thought the aid would be very beneficial for classroom training in tactical decision making.

During the development of the aid, there was some question whether users would have difficulty understanding and applying the scoring and weighting rules. The present analyses indicate that there were indeed some problems, but inconsistencies were not large and users would be able to overcome these with additional instruction and practice. Interestingly, there were consistent differences in the number of errors committed by participants using the two scenarios. Apparently the richer, more detailed Jayhawk scenario provided a sufficiently complex context such that users were unsure, hence inconsistent, about appropriate value and weight assignments. This is a particularly important finding since real battlefield situations will be exceedingly complex compared to the scenarios; it may well be that consistency will be even further reduced in such circumstances. However, these inconsistencies may be outweighed by the benefits gained from a systematic analysis and evaluation of alternative courses of action.

Although there was little change in the orders of the preferred courses of action, there was an increase in the number of factors considered after using the aid. This is particularly encouraging since there has been previous concern that decision makers do not incorporate sufficient factors in their analyses. It is anticipated that with extensive practice, users will become more comfortable in relying on the aid as a memory bank, thus allowing them to evaluate many more factors.

One of the greatest potential advantages of this decision aid is the feedback provided by the sensitivity analysis. This feedback indicates, based on the user's inputs, which factors are most sensitive to changes in the weight assignments. Although the effect of providing this type of feedback on subsequent decision making was not specifically evaluated, all participants reported it would be helpful in their analyses by giving them better insight into their own judgment structure.

In terms of continued evaluation and implementation of the aid, the present evaluation indicated two promising approaches. One would be to incorporate the aid into an ongoing tactical simulation in which a commander and staff could actually use the aid in making decisions. A second approach involves using the aid as a training device in teaching tactical decision making. Students could work through a problem using the aid and compare their input values and weights, as well as solutions, with the instructor's. This would be helpful not only in identifying errors but also by providing a focus for discussing factors on which there is disagreement.

Based on the present evaluation, the structure and format of the aid seem quite adequate. Directions for any further modifications will appear only after the aid has been implemented and used in either a classroom or a tactical decision-making context.

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