Research Product 94-09

Evaluation of the AirLand Battle Management Advanced Technology Demonstration Prototype Version 1.2: Knowledge Base Assessment of the Avenue of Approach Comparison Tool

April 1994

Field Unit at Fort Leavenworth, Kansas
Manpower and Personnel Research Division

U.S. Army Research Institute for the Behavioral and Social Sciences

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Sharon L. Riedel
U.S. Army Research Institute

Paul E. McKeown, and James P. Flanagan
CAE-Link Corporation

Leonard Adelman
Decision Systems Research

Field Unit at Fort Leavenworth, Kansas
Stanley M. Halpin, Chief

Manpower and Personnel Research Division
Zita M. Simutis, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
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EDGAR M. JOHNSON
Director

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CAE-Link Corporation

Technical review by

Charles Allen III
Mary C. Berwanger
Battle Command Battle Laboratory,
Combined Arms Command, Fort Leavenworth, Kansas

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Riedel, Sharon L. (ARI); McKeown, Paul E., Flanagan, James P. (CAE-Link); and Adelman, Leonard L. (Decision Systems Research)

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13. ABSTRACT *(Maximum 200 words)*

This report documents subject matter experts' (SMEs) assessments of the knowledge base of the Avenue of Approach Comparison Tool (AACT), a module of the AirLand Battle Management (ALBM) Advanced Technology Demonstration (ATD) decision aid prototype, version 1.2. This is one of a series of assessments of the ALBM ATD prototype conducted during its development. AACT analyzes and rank orders automatically or manually generated Avenues of Approach (AAs) for tactical planning. It rank orders the AAs using a Multi-Attribute Utility Analysis approach and an automated terrain data base. SMEs judged the AACT ability to query the automated terrain data base for terrain data to be very useful. However, the underlying procedures and analysis factors, as they are at this time, may not yield acceptable results. Suggestions for improvement are provided.

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CAE-Link Corporation
Suite #300, 5111 Leesburg Pike
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FOREWORD

This document contains the results of an early assessment of the Avenue of Approach Comparison Tool, a module of the AirLand Battle Management (ALBM) Advanced Technology Demonstration (ATD) prototype, version 1.2. ALBM ATD is a program to develop decision aid prototypes to support Army division-level tactical planning. This assessment is one of a series of life cycle assessments of ALBM ATD being conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) during the development of the system. The results will be used by the developer and government sponsors of ALBM ATD to guide further development of the system.

The research was conducted under the ARI research task entitled "Support for Command and Control Research." The assessment was in support of the Combined Arms Command (CAC), the program's user representative. A Memorandum of Agreement was in effect with the Combined Arms Combat Developments Activity, "Development and Implementation of the Future Battle Laboratory," dated 30 June 1989. The results of this review were briefed to personnel from the Battle Command Battle Laboratory, Combined Arms Command; Communications and Electronics Command; Lockheed; and MITRE on 7 January 1993. Brigadier General Anderson, Deputy Commanding General for Combat Developments, Combined Arms Center, was briefed on the findings presented in this report on 25 January 1993.

EDGAR M. JOHNSON
Director

EVALUATION OF THE AIRLAND BATTLE MANAGEMENT ADVANCED TECHNOLOGY DEMONSTRATION PROTOTYPE VERSION 1.2: KNOWLEDGE BASE ASSESSMENT OF THE AVENUE OF APPROACH COMPARISON TOOL

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Summary

This report documents the results of a knowledge base evaluation of the Avenue of Approach Comparison Tool (AACT), one module of the AirLand Battle Management (ALBM) Advanced Technology Demonstration (ATD) set of decision aid prototypes. The assessment was conducted of ALBM ATD version 1.2, an interim prototype and not the final version. AACT analyzes and rank orders automatically or manually generated Avenues of Approach (AAs) using a Multi-Attribute Utility Analysis (MAUA) approach. AACT can use system embedded or user specified criteria to evaluate the AAs. Three subject matter experts were given a detailed description of the knowledge and procedures used to derive the AACT products and asked to judge the validity and acceptability of the procedures, knowledge, and products. SMEs judged the AACT ability to query the automated terrain data base for terrain attributes of specified areas to be very useful. However, the method used to sample the automated terrain data for input into the MAUA procedure, the use of non-doctrinal analysis factors, the weighting and terrain data scoring procedures were not acceptable. An analytic assessment of the MAUA methodology showed that accepted MAUA methods were not adhered to: MAUA factors and sub-factors were duplicated or correlated, and the factor weighting and scoring methods were incompatible with each other. Although this tool has potential to improve the quality and timeliness of AA comparisons in tactical planning, the underlying procedures and analysis factors of this tool, as they are at this time, may not yield acceptable results.

Introduction

Overview

This report documents one of six assessments of version 1.2 of the Airland Battle Management (ALBM) Advanced Technology Demonstration (ATD) prototype conducted by the U.S. Army Research Institute (ARI). The assessments are part of a set of life cycle evaluations being conducted on the ALBM ATD prototype as it is being developed. The version 1.2 prototype is an interim prototype and not the final deliverable version. The purpose of the life cycle evaluations is to provide user and subject matter expert feedback to the government sponsor and contractor developer during the development of the prototype in order to guide the design and development of the system and to provide information for management decisions. In this way, it is hoped that the final operational system will have capabilities that will improve user performance. The ARI assessments are in support of the Battle Command Battle Laboratory in its role as the users' representative in the ALBM ATD program.

The assessments conducted on the version 1.2 prototype include knowledge base reviews of four tools, a human factors assessment of the interface, and a user and SME review of demonstrated prototype capabilities. These assessments are documented in separate ARI reports (Flanagan, in preparation; McKeown, in preparation-a, in preparation-b; Rappold & Flanagan in preparation). This report contains the results of a review of the knowledge base of the Avenue of Approach Comparison Tool, one module of the ALBM ATD prototype.

The objectives of the evaluation reported here are to assess the completeness and acceptability of the AACT procedures and products, as reported by subject matter experts.

Description of ALBM ATD

ALBM ATD is a Training and Doctrine Command (TRADOC) and Army Materiel Command (AMC) program. Its purpose is to develop decision aid prototypes based on advanced technologies and transition them to the Army Tactical Command and Control System (ATCCS). The decision aids are intended to support corps, division and brigade level commanders and their staffs in tactical planning operations. The Communications and Electronics Command at Fort Monmouth is responsible for the overall management of the program; the Combined Arms Command, Combat Developments at Fort Leavenworth is the users' representative responsible for functional requirements, knowledge elicitation with subject matter experts, and the operational evaluations; and the Program Executive Office for Command and Control Systems (PEO-CCS) is responsible for integration with the Army Tactical Command and Control System (ATCCS).

Two Force Level Control (FLC) Advisors are currently under development as part of the ALBM ATD system - MET4 and FITE. MET4 (Mission, Enemy, Terrain, Troops and Time Available Tools) is intended to aid commanders and their staffs from brigade through corps to analyze the area of operations and to assess the enemy and friendly capabilities. FITE (Force Interactive Tactical Evaluator) interacts with MET4 to aid commanders and their staffs to develop, wargame, and compare COAs.

MET4 has four basic components.

- Battlefield Area (BA) Component assists commanders and staff to analyze the terrain and develop and analyze avenues of approach.

- The Enemy Situation and Capabilities (ESC) Component interacts with the other MET4 components to aid commanders and staffs to anticipate enemy operations. Its principal focus is on probable enemy courses of action.

- Friendly Situation Capabilities (FSC) Component interacts with other MET4 components to assist commanders and staffs to analyze missions received from higher headquarters to assess the friendly situation and to determine the general ability of the unit to accomplish its assigned mission. The focus is on projecting friendly unit readiness and capabilities.

- The Execution Monitor (EM) Component interacts with ATCCS components, FITE, other MET4 components, and other decision aids to aid commanders and staffs to monitor current operations. It alerts commanders and staffs when the current operation deviates from the Operations Order (OPORD), aids commanders and staffs to determine when orders should be issued to implement new phases or branches provided for in the current plan, and when modifications of the current plan or replanning are necessary.

The second ALBM ATD module, the FITE, interacts with MET4 to aid commanders and staffs to develop, wargame, and compare Courses of Action (COAs). It also aids commanders and staffs to properly synchronize operations of subordinate and supporting units in order to concentrate combat power at the critical place and time to accomplish the commanders intent. Its principal focus is on COA development, preparation of the COA sketch, COA analysis (wargaming) and comparison, and on an execution synchronization matrix.

Description of the Avenue of Approach Comparison Tool

AACT will analyze and rank order friendly or enemy avenues of approach that have been generated either automatically by ALBM ATD or manually by the user. The AAs can be assessed using either the parameters and terrain data already embedded in the system or users can specify and define their own parameters and data for use in system calculations. In the case of user specified parameters, the user must provide data for each AA being evaluated on each parameter.

Figure 1 presents an AACT Main Comparison Screen showing overall AA rankings and AA rankings on each parameter. For the rankings on the individual parameters, the AA with the best score on a given parameter is given a green circle, the AA with the worst score is given a red circle, and all AAs in between yellow circles. At the bottom of the screen, the relative ranking of the AAs is presented, with the best AA being ranked "1".

Users specify on the Main Comparison Screen whether the friendly operation is offensive or defensive. By doing this they also indicate whether the AAs being analyzed are friendly or enemy. If the friendly mission is defensive, then the AAs will be enemy AAs. If the mission is offensive, the AAs will be friendly AAs. However, AACT analyzes both friendly and enemy AAs from the perspective of what is good from the point of view of the friendly force. This means that the AA ranked "1" or best on the Main Comparison Screen will be good for the friendly force, whether it is a friendly or enemy AA. If it is a enemy AA, "1" means then that it is bad for the enemy.

AACT uses a multi-attribute utility weighted additive model to derive the AA ranks. An overall score for each AA is calculated by summing weighted scores on each parameter, where the AA score on each parameter is the sum of weighted scores of a set of sub-parameters. Sub-parameter values are calculated by summing the weighted values of component elements. Figure 2 shows the set of system specified parameters, sub-parameters, and data items used in the AACT MAUA analysis. The user can specify different parameters and subparameters to be used in the analysis, but must enter his own data values for each new parameter.

Data for elements are obtained from the ALBM ATD terrain database. Table 1 shows the terrain data defining each parameter, sub-parameter and element. The raw data are transformed so that scores for the different elements have similar scales and can be added. Each element has a transformed score between 0.0 and 1.0. The AA with the best raw score value for an element will receive a score of 1.0 and the AA with the worst raw score will receive a score of 0.0. All other AAs will receive a value proportionately between these two values.

For each element the user must indicate whether high scores for the element are favorable or if low scores are favorable. This, of course, depends on the mission. The Software User's Manual (Lockheed, 1992) gives an example (p. 136). "There is an

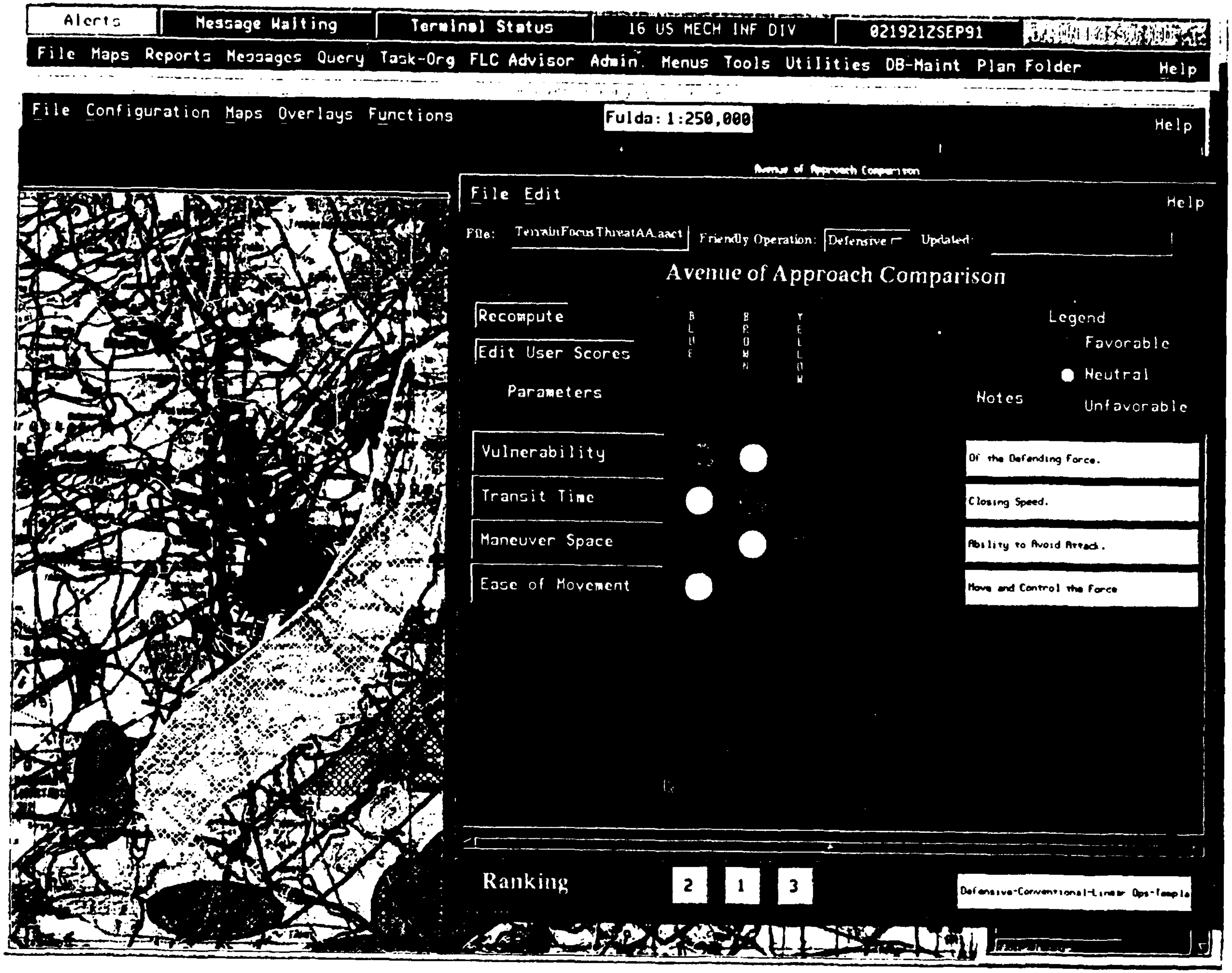

Figure 1. Avenue of Approach Comparison Tool--overall comparison display

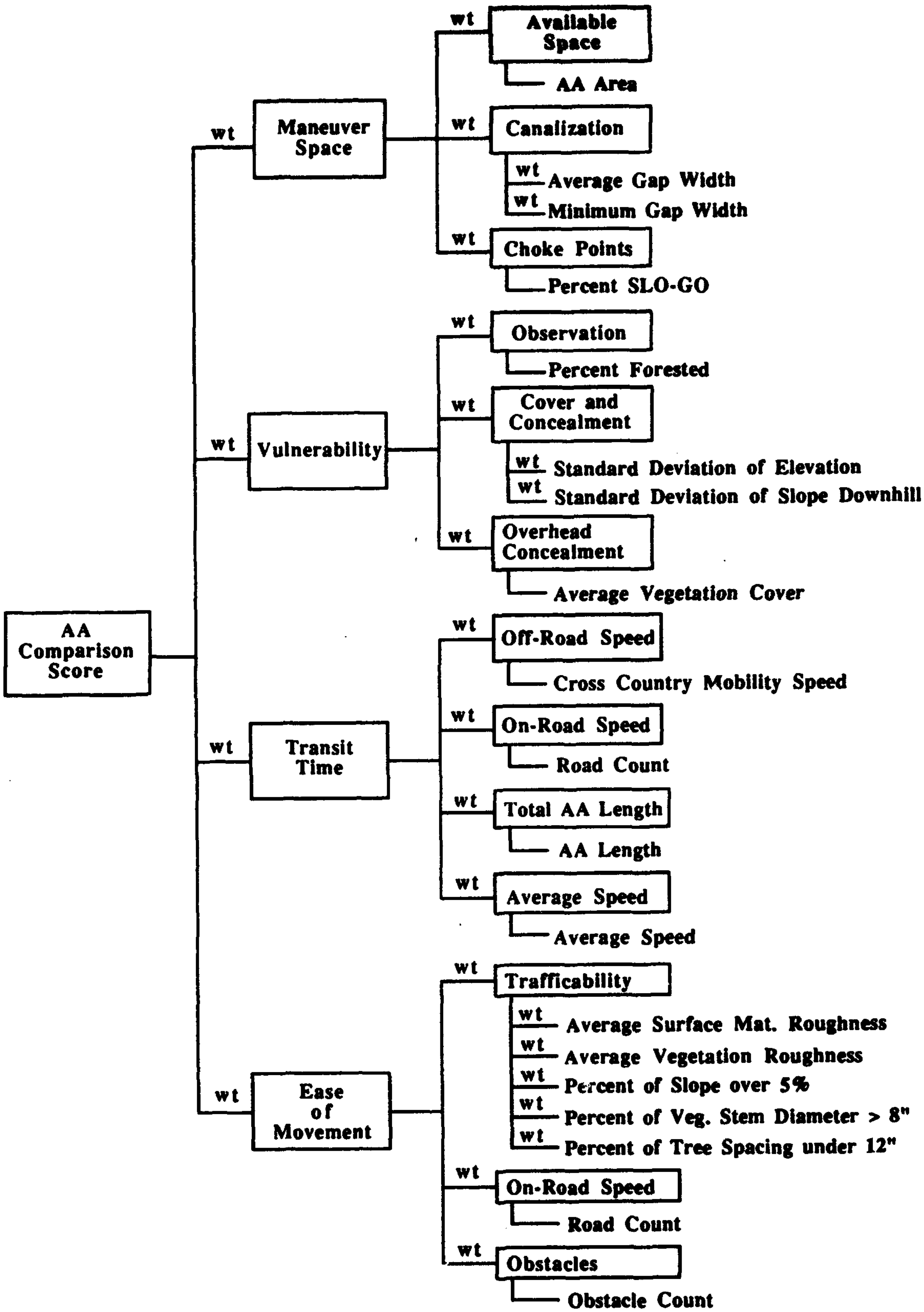

Figure 2. AACT overall Avenue of Approach (AA) comparison score, showing default parameters, subparameters, and terrain elements

Table 1. Avenues of Approach (AA) Comparison Parameters, Subparameters, and Element Descriptions

Parameter	Sub-Parameter	Element	Element Description
Vulnerability	Observation	Percent Forward	Percentage of **sampled** AA terrain data that is forested
	Cover & Concealment	Standard Deviation of Elevation	Standard deviation of the elevation values for **sampled** AA terrain data
		Standard Deviation of Slope Downhill	Standard deviation of the slope vectors (amount of slope and direction of slope) for **sampled** AA terrain data
	Overhead Concealment	Average Vegetation Cover	For **sampled** AA terrain data that is forested with vegetation height over 12 feet, the average of the values for % canopy closure (non-forested areas or areas with vegetation height under 12 feet are included in the average, but with a value of 0% canopy closure)

Table 1. Avenues of Approach (AA) Comparison Parameters, Subparameters, and Element Descriptions (Continued)

Parameter	Sub-Parameter	Element	Element Description
Transit Time	Off-Road Speed	Cross Country Mobility Speed	Using the relative amounts of NO-GO, SLOW-GO, and GO terrain in the AA, and the unopposed movement rates for mechanized forces from ST 100-9, the time, in hours, required to transit the entire length of the AA
	On-Road Speed	Road Count	The number of road segments in the entire area of the AA (a road segment is a single straight line of a connected series of straight lines that defines the road)
	Total AA Length	AA Length	The length of the AA along the centerline from start to end
	Average Speed	Average Speed	The length of the AA, divided by the time required to transit the length of the AA
Maneuver Space	Available Space	AA Area	The computed area within the boundaries of the AA
	Canalization	Average Gap Width	The average width of the AA along its entire length
		Minimum Gap Width	The minimum width of the AA along its entire length
	Choke Points	Percent SLOW-GO	The percentage of the entire AA area that is classified as SLOW-GO

Table 1. Avenues of Approach (AA) Comparison Parameters, Subparameters, and Element Descriptions (Continued)

Parameter	Sub-Parameter	Element	Element Description
		Average Surface Material Roughness	The average value of Surface Material Roughness for sampled data within the AA (values run from 0 to 1 as a multiplier of mechanized movement speed: a value of 1 means to degradation of speed due to the terrain surface, and a value of 0.8 means mechanized forces move at 80% of their normal speed)
		Average Vegetation Roughness	The average value of Vegetation Roughness for sampled data within the AA (values run from 0 to 1 as a multiplier of mechanized movement speed: a value of 1 means no degradation of speed due to vegetation on the terrain surface, and a value of 0.8 means mechanized forces move at 80% of their normal speed)
Ease of Movement	Trafficability	Percent of Slope over 5%	Percent of sampled data in the AA that has a slope of more than 5%
		Percent of AA with Vegetation Stem Diameter over 8 inches	Percent of sampled data in the AA that has stem diameters of more than 8 inches
		Percent of AA with Tree Spacing less than 12 Feet	Percent of sampled data in the AA that has tree spacing less than 12 feet
	On-Road Speed	Road Count	The number of road segments in the entire area of the AA (a road segment is a single straight line of a connected series of straight lines that defines the road)
	Obstacles	Obstacle Count	The number of individual obstacles that lie partially or wholly within the AA, or that pass through the AA

element called %SLOPE>5%. This element indicates the percentage of the overall area covered by the AA that has a percent slope greater than 5% since this will effectively degrade tank movement. Now if you are on an attack mission, then you would want to minimize such areas, so low scores would be favorable. If you were defending from fixed positions, then you would want to maximize such areas and high scores for the AAs would be favorable."

Scores for a number of the elements are obtained by sampling the terrain data in the automated terrain data base. The technique used is to construct a grid of equal intervals arranged such that about 100 points of data are extracted from the terrain data.

Importance weights for each parameter, sub-parameter and element are assigned by the user. Weights are assigned by considering the contribution each item makes to the next higher item of which it is part. Elements are weighted within their sub-parameters, sub-parameters within their parameters, and parameters within the total score. The user adjusts sliders on the computer screen to weight each on a scale of 1 to 10. Weights within each level are automatically normalized so that they range from 0 to 1 and sum to 1.

Weighted element scores are added to yield their sub-parameter scores. Weighted sub-parameter scores are added to yield parameter scores and weighted parameter scores are then added to yield an overall value score for each AA. AAs are ranked based on their overall score and assigned a numerical ranking, with "1" given to the best AA, i.e. the AA most favorable to friendly forces.

Knowledge Base Assessment

Evaluation Issues. Evaluation issues were (1) Are the AACT procedures complete? (2) Are the procedures and algorithms acceptable to the SMEs? (3) Would the results of the procedure be useful to G2 staff?

Approach. Each Subject Matter Expert was interviewed individually for approximately four hours by two evaluators. The evaluators described the underlying data base and procedures and collected data by means of questionnaires, recording verbal comments, and interview questions. The SMEs were not shown the actual software, but the algorithms were described using slides and written descriptions. The sessions were videotaped.

Limitations. In the documentation available to this point there is scant reference to doctrinal sources for the methods, parameters and algorithms used in the AACT. This made assessment of AACT's compatibility with doctrine difficult. Participants in the assessment were three subject matter experts. This somewhat limits the generalizability of the results and conclusions. However, the SMEs were generally in agreement.

Method

Participants

SMEs were three Army officers with training, experience, and current positions related to the G2 staff. Two are G2 Observer/Controllers for the Battle Command Training Program. One was a Captain with Combined Arms Command Threats at Fort Leavenworth. Table 2 gives a description of their education and experience.

Documentation of Algorithms and Procedures

Descriptions of the AACT algorithms and procedures were obtained from ALBM ATD Detailed Design Review packages, Software User's Manual for the ALBM ATD Force Level Control Advisor System (Lockheed, 30 May 1992), and AACT software READ.ME files, HELP files, and Explanation capability. Information on Army doctrinal procedures, used for comparison with AACT procedures, was obtained from FM-101-5, Staff Organization and Operations; ST 100-9, The Command Estimate; FM 5-33, Terrain Analysis; and FM 34-130, Intelligence Preparation of the Battlefield.

Procedure

SMEs were tested in individual four hour sessions. The AACT algorithms, procedures, and terrain data were described in detail using a slide projector and paper handouts. Actual AACT software was not shown on the computer. Appendix A contains a copy of the slides that were shown to describe the AACT algorithms and procedures. Following is a summary of the material presented.

- Description of ALBM ATD Program and User Evaluations
- Summary of Doctrinal Terrain Analysis and AA Comparison Procedures in Tactical Decision Making
- Doctrinal AA analysis factors
- Description of AACT cognitive map for AA Comparisons
- AACT process used to score and rank AAs
- AACT comparison parameters, sub-parameters, and elements
    - Data Collection: Questionnaire on validity of definitions
    - Data Collection: Cross Walk of OCOKA and AACT comparison factors
- AACT terrain sampling technique
    - Data Collection: Questionnaire on validity of sampling technique
- AACT weighting technique
    - Data Collection: Questionnaire on validity of weighting technique
    - Data Collection: Overall usefulness and validity of procedures

Table 2. Demographic Description of Subject Matter Experts

Information		SME A			SME B			SME C		
Service	Rank	MAJ (P)			CPT			LTC		
	Time in Grade	5 years			6.5 years			1 year		
	Time in Service	17 years			10.5 years			18 years		
	Current Position	BCTP O/C - Intell			Threat Oper'ns			BCTP O/C - Intell		
Education	Highest Military School	CGSOC			CAS[3]			CGSOC		
Tactical Position	Echelon	Bn	Bn	Div	Bde	Bn	Det	Bde	Bn	Plt
	Unit Type	Inf	MI	Inf	CTC	Inf	MI	MI	Arty	Inf
	Position	S2	S3 Ops	Asst G2 Ops	Bde S2 O/C	S2	Cmd	S3	S2	Cmd
	Months Service	39	18	8	24	42	25	24	6	6

Notes:

Arty	Artillery
BCTP O/C	Battle Command Training Program Observer/Controller
Bde	Brigade
Bn	Battalion
CAS[3]	Combined Arms Services Staff School
CGSOC	Command and General Staff Officers Course
Co XO	Company Executive Officer
CTC	Combat Training Center
Det	Detachment
Div	Division
Engr	Engineers
Inf	Infantry
MI	Military Intelligence
Plt	Platoon
SME	Subject Matter Expert

Data were collected using questionnaires, talk aloud procedures, and structured interviews. Participants' verbal comments were recorded by one of the interviewers. The sessions were also videotaped and verbal comments were transcribed for content analysis. Appendix B contains a copy of questionnaires administered.

In addition to an assessment by SMEs, an expert in MAUA analyzed the MAUA technique used in AACT and assessed its validity.

Results and Recommendations

This section summarizes SMEs' verbal comments (see Appendix C) and gives the results of the questionnaires that were administered (see Appendix B). Also included are Human Factors observations, and the results of an analytic assessment of the MAUA method used. Where appropriate, recommendations are made.

Compatibility With Doctrine

Issue

Are the content and organization of evaluation parameters in AACT compatible with doctrinal procedures and parameters?

Results

Table 3 shows the results of the cross-walk between doctrinal OCOKA (Observation, Cover and Concealment, Key Terrain, Obstacles and Adequacy of Maneuver Space) AA evaluation factors and AACT analysis parameters and subparameters. Appendix C contains SMEs' verbal comments related to doctrinal compatibility. SMEs believed most of the OCOKA factors, with the exception of Key Terrain, were represented somewhere in the AACT sub-parameters. Of more importance may be the mixing and recombining of the sub-factors into major factors that are different from OCOKA. For example, the AACT parameter Vulnerability is a combination of OCOKA Cover and Concealment and Observation and Fire. Users have been taught and are familiar with the doctrinal factors. A similar but different AACT analysis structure makes the comparison task confusing to the users.

SMEs said the AACT parameter Vulnerability is non-doctrinal and does not have a standard meaning. Similarly, the AACT elements Vegetation Roughness and Surface Material do not have standard tactical meanings. The AACT parameters of Trafficability, Cover and Concealment, and Choke Points do not have the same meaning as the same doctrinal terms.

Parameters and sub-parameters that SMEs said should be added include Key Terrain, line-of-sight, terrain configuration, man-made obstacles, size and location of obstacles, rivers, and location and classification of bridges. Threshold values of measures such as slopes, stem diameters, and tree spacing should use doctrinal values.

On the questionnaire (see Appendix B-1), two participants judged that AACT method was not compatible with the doctrinal method of comparing AAs. They said that AACT uses some non-doctrinal terms and non doctrinal standards. Key items of OCOKA, i.e. rivers and towns, key terrain, mobility corridors, are

Table 3. Match of Doctrinal AA Comparison Factors With AACT Factors

Doctrinal AA Factors (OCOKA)	AACT Factors (suggested additions are underlined)		
	SME A	SME B	SME C
Observation and Fire	% Forested Std Dev of Elevation Std Dev of Slope Downhill <u>Add line-of-sight</u>	% Forested Ave Vegetation Cover <u>Add line-of-sight</u> <u>Add terrain configuration</u>	% Forested Std Dev of Elevation Std Dev of Slope Downhill Ave Vegetation Cover <u>Add line-of-sight</u>
Cover & Concealment	% Forested Ave Vegetation Cover	% Forested Ave Vegetation Cover <u>Add line-of-sight</u> <u>Add terrain configuration</u>	% Forested Std Dev of Elevation Std Dev of Slope Downhill Ave Vegetation Cover <u>Add line-of-sight</u>
Obstacles	Obstacles <u>Add man-made obstacles</u>	Obstacles <u>Add man-made obstacles</u> <u>Add size and location</u>	Obstacles <u>Add man-made obstacles</u>
Key Terrain			
Adequacy of Maneuver Space	Available Space	Off-Road Speed On-Road Speed AA Length Average Speed Available Space Canalization Choke Points Trafficability On-Road Speed	Available Space Canalization Choke Points
Ease of Movement	Off-Road Speed On-Road Speed AA Length Average Speed Canalization Trafficability On-Road Speed	Off-Road Speed On-Road Speed AA Length Average Speed Trafficability On-Road Speed	Off-Road Speed On-Road Speed AA Length Trafficability On-Road Speed

ignored or de-emphasized. The third participant said that AACT was generally compatible, with the exception of its terminology. SMEs unanimously agreed that the AACT factors, definitions and terminology should be doctrinal.

Discussion

Non-doctrinal parameters, and parameter organization and definitions present a number of problems for using AACT. First, soldiers learn the doctrinal terrain analysis framework and then are required to learn a new framework to use AACT. Under stress, memory of the new framework and definitions will degrade and the user may revert to using the OCOKA framework and definitions that are better known to him. Especially in performing the weighting, the definitions given to the parameters are important. If the meaning users give to the parameter names is different from how those parameters are defined using the AACT elements, users could be weighting a parameter that is different from what they think it is, and the results of the AACT comparisons would not reflect the users intentions. Or users may have to look at the elements to recall how AACT defines the parameters if AACT definitions don't match normal usage of those words. Here he may lose valuable time. At a minimum, by imposing an alternative framework of terrain factors and definitions, AACT increases the soldiers' mental workload in using the system. More importantly, having two competing frameworks for performing terrain analysis greatly increases the probability of errors in using AACT.

AACT does provide the option for users to enter their own parameters, sub-parameters, definitions, and terrain data scores. However, manually deriving terrain data scores for can be difficult, time consuming and labor intensive. By exercising the option to specify their own parameters, users do not make use of one of the major advantages of AACT - the automated terrain data base. Further, novice users and users under time or situational stress, will tend not to take the time and trouble to redefine the parameter framework and calculate their own data scores.

Recommendations

Restructure the parameters, sub-parameters, elements, and terminology to conform to the OCOKA structure and definitions described in the doctrinal literature.

Parameters, Subparameters, and Elements

Issues

Is the parameter set complete? Are the definitions of the parameters, subparameters and elements acceptable?

Results

This section reports the results of SMEs verbal comments and questionnaires (see Appendix C) with regard to the parameters, subparameters and element set in AACT. SMEs said the following definitions were questionable.

Maneuver Space. This parameter is defined, in part, as total area within the AA. This means that, in AACT, the longer the AA the greater will be the value of the Maneuver Space parameter. SMEs said this definition does not capture the meaning of the term as it is commonly used in tactical planning, i.e. freedom of the force to maneuver as it advances along the AA. One could have a long narrow AA with barely enough room for brigade passage. Here AACT would give a large value to the Maneuver Space parameter, but the brigade would have little room to maneuver. One SME said that available space is more important at deployment lines and at the end of the AA, i.e. planners need to know mobility corridor space at critical points along the AA.

Vulnerability. This parameter is a non-doctrinal term without a standard meaning. As such, users will have to examine its sub-parameter and element definitions before weighting it, which makes weighting difficult. Using it in a briefing of AA analyses makes communication more difficult because its meaning is not what the audience would intuitively understand it to mean.

Observation. This parameter is defined as percent forested. SMEs said location of the forest is more important than the percentage. The definition should also include line-of sight data.

Cover and Concealment (C & C). This sub-parameter is defined as standard deviation (SD) of elevation and SD of slope down hill. These elements may, in some situations, be misleading indicators of Cover and Concealment. For example, constantly sloping terrain (high value for SD of elevation) would not provide C & C. Or if one force is on a high ground with overwatch to a valley occupied by the other force, C & C is not provided to the second force. C & C should include forested areas. C & C ordinarily includes Overhead Concealment, which is a separate parameter in AACT. SMEs said SD of slope downhill is not commonly used. Its implications for C & C and its relationship to SD of elevation are not clear.

Overhead Concealment. This sub-parameter is defined as average vegetation cover. Effects of seasons and type of vegetation (e.g. deciduous or coniferous)should be considered.

Obstacles. This sub-parameter is defined as number of natural obstacles. Type, location and degree of difficulty of obstacles are also important. Add man made obstacles.

Choke Points. This sub-parameter is defined as percent SLO-GO terrain. SMEs said a choke point was something very specific, i.e. very narrow point along the AA.

Off-Road Speed. This sub-parameter and its element Cross Country Mobility are measured as time to transit length of the AA. The labels should reflect time rather than speed.

On-Road Speed. This sub-parameter is measured by the total number of road segments in the AA. On-Road Speed, measured in this fashion, is confounded with length of the AA. Longer AAs would have more road segments and thus score higher on On-Road Speed. SMEs also thought types of roads, road network, cross-compartmentalization, and whether the roads are parallel or cross roads are important to On-Road-Speed. In addition, the terminology here is not meaningful, i.e. speed measured by road count.

%Slope >5%. Slopes are a common measure of trafficability. However, doctrinally, slopes up to 30% are considered GO terrain. One SME recommended the use of a slope value that represented SLO-GO terrain. SMEs also recommended the addition of slope direction to this element. The user is required to indicate whether high values of this variable are favorable or unfavorable to friendly forces. To make this assignment the user needs to know the direction of the slope.

Additions. SMEs said Key Terrain should be added to the parameter set. The data for Key Terrain would have to be user specified, but SMEs thought a place holder for this parameter should be included.

Scoring of Data Elements

Issue

Is the method of scoring the elements acceptable?

Results

In an order to make the element scores comparable, raw data element scores are transformed by assigning "1" to the best AA element score for an element, "0" to the worst AA score and linearly interpolated values to the scores in between. On a questionnaire, SMEs were asked "How much confidence do you have in the scores that are calculated using the ALBM ATD procedure?" Two answered "Little Confidence" and one answered "No Confidence". See Appendix B-3 for the questionnaire and written comments. SMEs said the 0-1 scoring method could produce erroneous AA rankings if the raw scores were close. If an element were weighted heavily, nearly identical AA raw scores on an element would be widely different after being transformed and weighted. Participants said there should be a method to identify the significant differences between the elements. One suggested having a raw score data matrix available with significant differences highlighted.

Discussion

SME's said the scoring method could produce erroneous results. In addition, the low face validity of the scoring procedure for the SMEs suggests that users may have little confidence in AACT results and hesitate to use them.

A more complete discussion of the scoring issue is presented in the section "Technical Assessment".

Recommendations

Add an easily accessible data matrix showing element raw scores by AA, with significant differences highlighted. Implement suggestions in "Analytic Assessment" section.

Terrain Data Sampling

Issues

Is the sampling method used to calculate scores for the AA comparisons acceptable? Do SMEs have confidence in the method used to sample terrain data?

Results

In response to the questionnaire item "How adequate is this method for determining scores for use in AA comparisons?", one SME responded "Somewhat Adequate", one responded "Inadequate", and one "Somewhat Inadequate". Two SMEs indicated that they had little confidence in the sampling method, and one responded that he was "Somewhat Confident". See Appendix B-2 for written comments of the SMEs. SMEs said that the method assumes homogeneity of terrain. For example, one might get the same percent forested if the forest were evenly scattered over an area or if the forest were all in one part with the rest being bare. The implications for the AA comparison might be different depending on the location of the forested area. For example, the concentration of forested areas at the beginning, at the end or running along the side of the AA is usually more important than the percent forested area for the whole AA. The accuracy of the results of the sampling method also depend on the size of the area being sampled. Smaller areas have a higher probability of having homogeneous terrain.

Discussion

A related problem is that there is no indication of the expected range of error resulting from this sampling technique for various sizes of AAs. Consequently, there is uncertainty as to the accuracy of the element data being measured. This is further compounded by the scoring method discussed in the previous section. If the expected accuracy of the sampled data is 5%, and the raw data extracted for two alternative AAs differ by 3%, then awarding a maximum score to one AA and a minimum score to the second AA is very misleading.

Recommendations

Re-examine the validity of the sampling method.

Weighting of Parameters, Subparameters, and Elements

Issue

Is the method of weighting the parameters acceptable?

Results

In answer to the questionnaire item "How difficult was this rating procedure?", two SMEs answered "Somewhat Difficult" and one answered "Somewhat Easy". In answer to the question "How much confidence do you have in the weights you have given, all three answered "Somewhat Confident". See Appendix B-4 for the questionnaire and written comments.

One SME said it wasn't clear to him what the cumulative effect would be of weighting the separate levels (i.e. parameters, sub-parameters, and elements) and then aggregating up through the levels. SMEs were also concerned about the effect of duplicate elements. For example, Road Count is an element in both of the parameters Transit Time and Ease of Movement. By including Road Count twice its final effect will not be known to the users or controllable by them.

Another example of duplicate elements is the set of sub-parameters Average Speed, AA Length and Off-Road-Speed. The latter is measured by the time to transit the length of the AA.

Thus Average Speed is AA Length divided by Off-Road-Speed (or time to transit the AA), and AA Length and Off-Road-Speed are included twice in the parameter set.

Discussion

The weighting procedure appears reasonably easy to use. However, duplicate and correlated attributes could yield effective weights far different from what the users intend. SMEs perceive this, as users will, and their confidence in the final results is degraded. See the later section "Analytic Assessment" for a discussion of the technical validity of the weighting method.

Recommendations

Restructure the element, sub-parameter and parameter hierarchy to eliminate multiple use of attributes. Eliminate one level of parameters so that weights are aggregated through only two levels. Give users the option of viewing the cumulative weight of any sub-parameter or element with the capability of modifying the weights.

Overall Acceptability

Issues

Would the results of the AACT procedures be used? Is the method used by AACT generally acceptable?

Results

In response to the questionnaire item, "Would you use the results of this comparison procedure?" two SMEs were uncertain, and one said "Probably". To the question, "How acceptable is this method to you?", one said "Acceptable", one "Somewhat Acceptable", and one "Somewhat Unacceptable". SMEs liked and would use certain aspects of the system, particularly the capability to access automated terrain data. However, they all expressed reservations about the system and said it must be used with attention to unusual definitions of the parameters and other limitations.

Recommendations

If the recommendations made in various sections of this report are implemented, overall acceptability and SME confidence in the results of the tool will increase.

Human Factors Observations

A systematic Human Factors assessment of the AACT was not conducted. However, two aspects of the AACT that make it susceptible to user error should be mentioned. These are the color coding of AACT results on the Main Comparison Matrix screen and the meaning of the "best" AA.

Color coding of parameter ratings. The legend in the Main Comparison Matrix screen (see Fig. 1) says that green indicates a "Favorable" rating for an AA on a parameter, yellow indicates "Neutral", and red "Unfavorable". This is incorrect. Green only indicates that the AA ranks higher than the other AAs on a parameter, red that the AA ranks lower than the other AAs, and yellow is given to all AAs between the highest and lowest score. The highest score, i.e. green, could still be an unfavorable score on a parameter. Similarly, the lowest score relative to the other AAs, i.e. red, could be a favorable score on a parameter. Color only indicates relative ranking of the AAs. The choice of red, yellow and green for the AA rankings will be misleading even if the labels are changed. Soldiers have been taught to perceive red as alert, NO-GO, or unfavorable; yellow as caution, and green as favorable or GO. Changing the labels on these colors will conflict with this standard meaning for users. Recommend that other colors or number rankings be substituted for the red, yellow and green color coding, and that numerical scores be available to augment the color coding.

Meaning of the "Best" AA. The Main Comparison Matrix screen shows the overall ranking of the AAs, where "1" is given to the best AA, "2" to the second best, etc. There are two problems for users here. First, the meaning of the word "best" can vary. The Software Users' Manual (Lockheed, 1992) states that the meaning of best "depends entirely on how the users define the parameter set." Users indicate whether their operation is to be defensive or offensive. If the user gives the mission as offensive, the AAs they are evaluating are friendly AAs, and a favorable AA is one that's favorable to friendly forces. If their mission is defensive, that means that the AAs they are evaluating are enemy AAs, and a favorable AA is one that is favorable to friendly forces but is bad for the enemy. With a defensive mission, the best AA is the one "you would like the threat to choose for a main effort." (p. 130, Lockheed, 1992) In examining enemy AAs, users are likely to be most interested in the best AA for the enemy, that is the one the enemy is likely to choose, not the one the user would like him to choose. The user would be interested in the worst AA if his mission is defensive. A meaning that would be easier to the user to use would be best AA for whomever will be using the AA. If it's a friendly AA, it's best for friendly forces. If it's an enemy AA, it would be best for the enemy.

A second problem is that if the user wants to use different or additional parameters for evaluating the AAs, he is required to indicate whether high scores on the element are favorable or if low scores are favorable. The changing meaning of "best" makes setting element values very confusing for the user. This is relatively straight forward for an offensive mission. However, for a defensive mission the user must engage in mental gymnastics in order to decide whether high or low values are favorable. For example, there is an element called percent slope greater than 5%. If you are on an attack mission, you would want to minimize such areas and would specify low values to be favorable. On the other hand, if you were on a defend mission, low values would be good for an enemy AA but bad for you. So you would specify high values as favorable. It would be easier for users to specify high or low values as favorable if they could do it consistently in terms of what would make a good AA, regardless of whether that AA was friendly or enemy.

Recommend that the best AA be defined in terms of a good AA whether that AA is for the enemy or friendly forces. Place a definition of best AA on the Main Computer Matrix Screen.

Analytic Assessment

Issues

Is the MAUA method correctly implemented in AACT? Is the MAUA method appropriate for the decision problem?

Results and Recommendations

This section includes an analysis by Dr. Leonard Adelman of the AACT implementation of the MAUA method. See Appendix D for the complete analysis. The AACT implementation is problematic in four respects. First, the parameter, sub-parameter, and element hierarchy contains duplicate and correlated items. Second, the AACT scaling procedure for scoring the element raw data creates only linear functions. Third, the procedure used to transform the element scores is not compatible with the weighting procedure used. Fourth, the MAUA method uses a trade-off procedure which may not accurately reflect users' analysis procedures. These four problems can result in AA ratings which do not represent the users' intentions and mission objectives. The following discussion describes these problems in more detail.

Duplicate and correlated elements. If there are duplicate or elements that are correlated, an AA that scores well on a duplicate element could get an unfair advantage because the same element is included in the hierarchy more than once. There are a number of items that are duplicated in the AACT hierarchy (see Table 1). Road Count is included in both Ease of Movement and Transit Time. AA length is a factor in the sub-parameters AA

Length, Available Space, Average Speed, and Off Road Speed. Percent SLO-GO is included in both Choke Points and Off-Road Speed. What this means is that the importance weights users give to these items are not the actual weights used in the calculations of AA rankings. One procedure to correct for duplicate elements is to show users the cumulative weight given to the thirteen elements and to permit them to modify them if they seem inappropriate. The cumulative weight is obtained by multiplying the relative weights from the top to the bottom (element level) of the hierarchy and summing weights for the duplicate elements. By giving users an opportunity to view and modify the cumulative weight for each element, they might be able to adjust for any double counting of elements. A better solution is to restructure the hierarchy to eliminate duplicate and correlated attributes.

Linear scaling of element scores. Before the raw scores for the elements can be weighted and added together they must be transformed into a common scale. In AACT, this is done by assigning the best score a value of "1", and the worst score a value of "0". All element scores in between are given a transformed score proportional to their distance between the scores on the best and worst AA. That is, the element raw scores are scaled using a linear transformation. This is generally appropriate. However, it is possible that some of the transformations should be step functions. For example, the user may not care what the average surface roughness value is for medium and large tanks unless it exceeds a certain value. So the transformed value for scores below the cut off value would be one, and above the cut off would jump down to zero. It is recommended that a sensitivity analysis be conducted to assess the sensitivity of the AA rankings to type of utility function.

Incompatibility of weighting and element score scaling procedures. The four main parts of the MAUA procedure are (1) the parameter hierarchy, (2) raw scores for the bottom level parameters in the hierarchy, in this case the elements, (3) a scaling method to convert element scores into a common scale so that scores on the different elements can be added, and (4) a method to weight the converted parameter, sub-parameter, and element scores. AACT uses importance weights, ie. the general importance of one parameter over another without regard the values of the parameters. Use of importance weights should be paired with an absolute scaling approach. The absolute scaling approach uses the parameter's natural scale going from lowest possible to highest possible and then converts the natural scale to a utility scale based on the comparative values of the natural scores. Each element of each AA to be assessed is measured using its natural scale and then converted using the utility scale.

However, instead of using an absolute scaling approach, AACT uses a relative scaling approach to obtain converted scores.

There is no absolute utility function that is used to convert raw scores to utility scores. In AACT the best AA on an element is given a "1", and the worst AA is given a "0" on the element. For example, on the element percent forested, AA "A" might measure 20% and AA "B" might measure 22%. The scaled score would be "0" for A and "1" for "B" even though the actual differences between the two may be trivial. The element AA Length might be 5 miles for AA "A", and 20 miles for AA "B" giving scaled scores of 1 for AA "A" and 0 for AA "B". If the User gave weights for Percent Forested and AA Length as general importance weights without regard for the actual element scores, he might weight Percent Forested as 7 and AA Length as 3. In this case AA "A" would be ranked highest even though the source of its superiority, Percent Forested, represents a trivial advantage.

Total score = Sum of (wt x scaled score)
"A" score = 7x1 + 5X0 = 7
"B" score = 7x0 + 3X1 = 3

With the type of scaling that AACT uses, "Swing Weights" should be used rather than the importance weights. "Swing Weights" describe the relative importance of the difference between the worst and best alternatives on a parameter. In the above example, users would give "Swing Weights" by saying how important a difference of 2% on Percent Forested is compared to a difference of 15 miles on AA Length. Even though abstractly Percent Forested might be more important than AA Length, 15 miles difference in length would probably be more important for AA goodness than a 2% difference in Percent Forested.

It is recommended that AACT use either general importance weights with absolute scaling or "Swing Weights" with the relative 0-1 scaling now being used. If the current scaling and weighting procedures are retained, users should be shown the range of natural scores on each element before doing the weighting. In this way elements, where the difference between AAs is trivial, can be weighted "0". Make sure the user understands the relationship between ranges and weights.

An alternative to using the 0-1 scaling is to use an absolute scaling approach which would then be compatible with the general weighting method. AACT already uses absolute scales at the element level because the scales are defined in terms of quantitative values, such as percentages and length. End points would be obtained as the lowest and highest practical values of each element and the remaining natural element scores converted using a linear transformation. A description of alternative MAUA weighting and scaling procedures is given in von Winterfeldt and Edwards (1986).

Appropriateness of the MAUA Trade-Off Method. MAUA uses a trade-off method where a high value on one parameter can compensate for low values on other parameters. However, in actual tactical planning there may be a minimum value on a parameter without which the AA is disqualified no matter how high other parameter values are. AACT procedures should be adjusted to deal with this possibility. For example, the user may be required to do a prescreening to eliminate AAs which do not meet minimum requirements on the elements.

Conclusions and Overall Recommendations

Overall, SMEs said AACT has a number of valuable features. They particularly liked the capability to access terrain data from an automated database. One said terrain analysis is so labor intensive that any help would be valuable. SMEs thought the tool would be useful as an analysis tool or to check their own analyses.

As it exists now, the design of AACT is not acceptable. The following general recommendations are made.

- Make the attribute definitions and terms doctrinal. New terms, concepts, and especially familiar terms with new meanings are difficult to use and easily lead to errors and misunderstandings.

- Change the element scoring or attribute weighting methods to make them compatible.

- Re-examine the validity of the sampling method.

- Add an option to easily access the terrain data for the AAs. Significant differences between AAs should be highlighted.

- Change the meaning of a best AA from best from the perspective of friendly forces to best from the perspective of the offensive position.

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APPENDIX A

SLIDES FOR DESCRIPTION OF ALGORITHMS AND PROCEDURES TO SMES

ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
Introduction

- Definitions
  - ALBM — AirLand Battle Management
  - ATTD — Advanced Technology Transition Demonstration
- ALBM ATTD Purpose
  - Define & refine operatinal requirements for automated decision aids for planning
  - Develop operational prototypes for Decision Aid Applications (DAAs)
  - Facilitate transition of DAAs to ATCCS
- Purpose of Operational Evaluation of ALBM ATTD
  - To ensure the needs of the user are considered in the development of the DAAs
- Types of Operational Evaluations of ALBM ATTD

Range of Applicability
Match of Requirements with DAA characteristics .
Requirements Validation
Utility
  Performance
  Usability
Knowledge Base - Procedures, algorithms, parameters
  Completeness
  Accuracy
  Adequacy

ALBM ATTD Knowledge Base Evaluation
AOAs in the Tactical Decisionmaking Process (ST 100-9)

Products In	Phase of Tact. Decisionmaking	Products Out	AOA Activity
Mission from Higher	Mission Analysis	Intel Estimate Restated mission Analysis brief Commander's guidance	Generate AOAs **Compare AOAs (to support analysis brief)**
Intel Estimate Restated Mission Commander's Guidance	Course of Action Development	COA statements and sketches Intel Estimate update COA brief	Generate AOAs (to support alternative COAs) **Compare AOAs**
COA statements and sketches Intel Estimate update Commander's approval	Course of Action Analysis and Comparison	Wargame results Decision matrices COA decision brief	Use approved AOAs
Commander's intent Wargame results	Decision and Execution	OPLAN/OPORD	Use approved AOAs

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis - ST 100-9, 1992

General Process

- Identify gaps (missing) in terrain data
- Develop terrain factor overlays
- Integrate weather
- Combine overlays
- Identify Avenues of Approach
- **Analyze Avenues of Approach**

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis, continued

Identify gaps in terrain data
Fill gaps with data from other units, imagery, reconnaissance

Develop terrain factor overlays

- Tree spacing, stem diameter
- Stream width, banks, velocity, depth
- Canopy closure, vegetation density
- Soil types
- Height of vegetation and built-up areas
- Slopes

Integrate weather

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis, continued

Combine overlays into GO, SLOW-GO, and NO-GO areas

Terrain Factor	NO-GO	SLOW-GO	GO
Man-made obstacles	Yes	No	No
Built-up areas	Over 500 meters wide, or not easily bypassed	Easily bypassed, or under 500 meters wide	Easily bypassed, or under 500 meters wide
Slope uphill	Over 45%	30 - 45%	Under 30%
Hard surface roads/trails (only if terrain is not open) **See Note below**	No road, and no more than 1 trail per km	Per km, 1 road, or 2 trails, or one of each	2 or more roads per km
Tree diameter and spacing	6-8 inches thick, and less than 20 ft spacing	2-6 inches thick, and less than 20 ft spacing	Under 2 inches thick, or over 20 ft spacing
Stream bank height	Over 4 ft	Under 4 ft	Under 4 ft
Stream attributes	Depth over 4 ft, or velocity over 5 ft/sec	Depth 2-4 ft	Depth under 2 ft
Elevation variation in one km	Over 200 meters	100-200 meters	Under 100 meters

Note: Except for Hard Surface Roads/Trails, if the terrain meets any of the criteria in the NO-GO column, then the terrain is NO-GO even if all other attributes are in the GO category. If the terrain is not open (e.g. restrictive tree diameter and spacing), then the existence of roads/trails may have the effect of raising the mobility of the terrain. For example, if two roads exist in an area, then restrictive tree diameter and spacing would not reduce the mobility to SLOW-GO or NO-GO.

Identify Avenues of Approach

- Determine mobility corridors

Corridors use GO terrain, avoid NO-GO areas, and occasionally use SLOW-GO terrain if necessary.

Mobility corridors are determined two echelons down from the planner's echelon.

Mobility corridors are non-directional unless slope dictates a direction.

Unit	Mob. Corr. Width
Division	6 km
Bde/Rgt	3 km
Bn	1.5 km
Co	.5 km

- Determine Avenues of Approach (AOAs)

AOAs are determined for the echelon below the planner, using two mobility corridors for the next subordinate echelon.

Echelon	AOA	Mob. Corridor
Corps	Division	Bde/Rgt
Division	Bde/Rgt	Bn

The two mobility corridors should not be too widely separated.

AOA	Mobility Corridor	Max. Separation
Division	Bde/Rgt	10 km
Bde/Rgt	Bn	6 km
Bn	Co	2 km

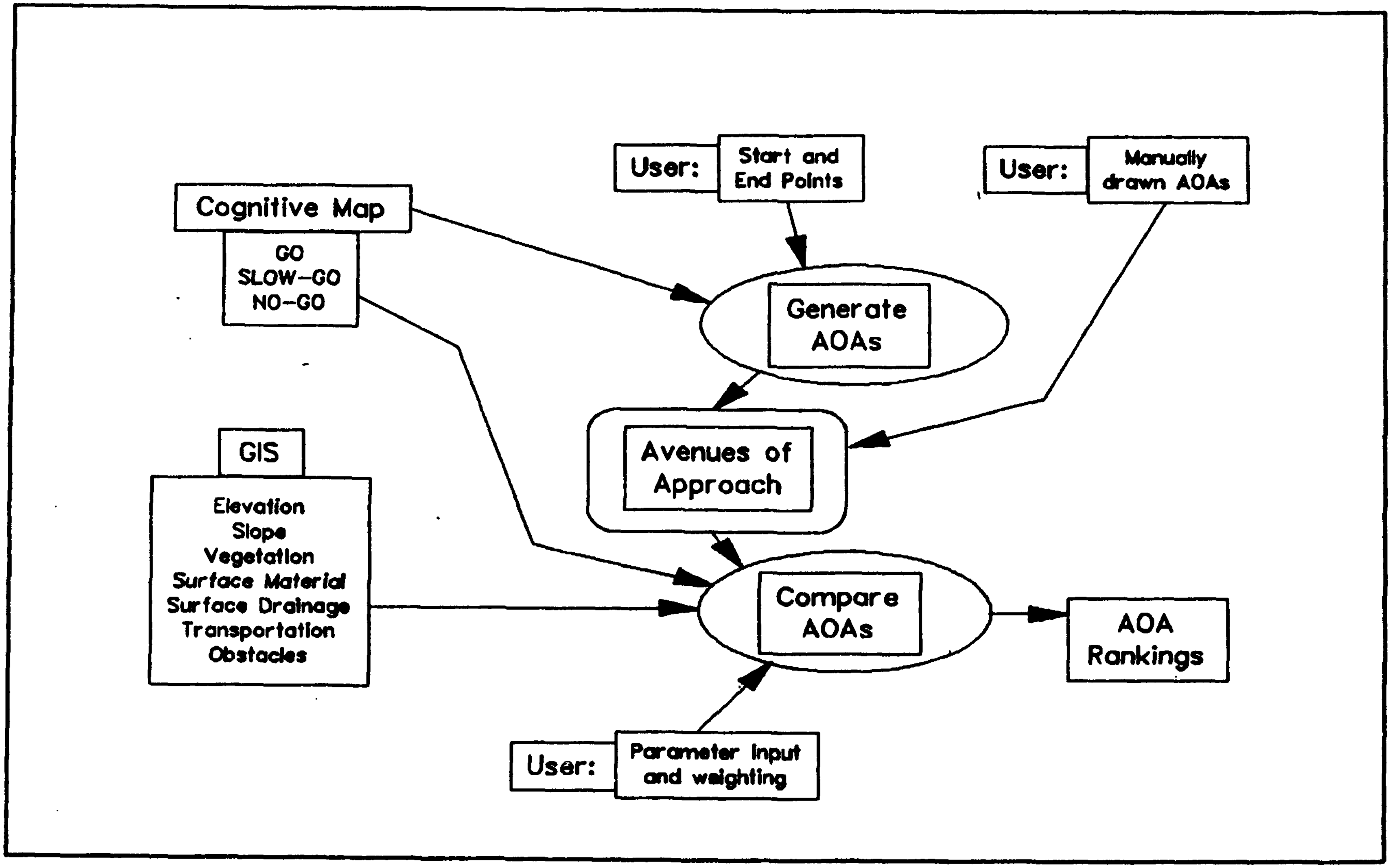
ALBM ATTD Knowledge Base Evaluation

Terrain Analysis, continued

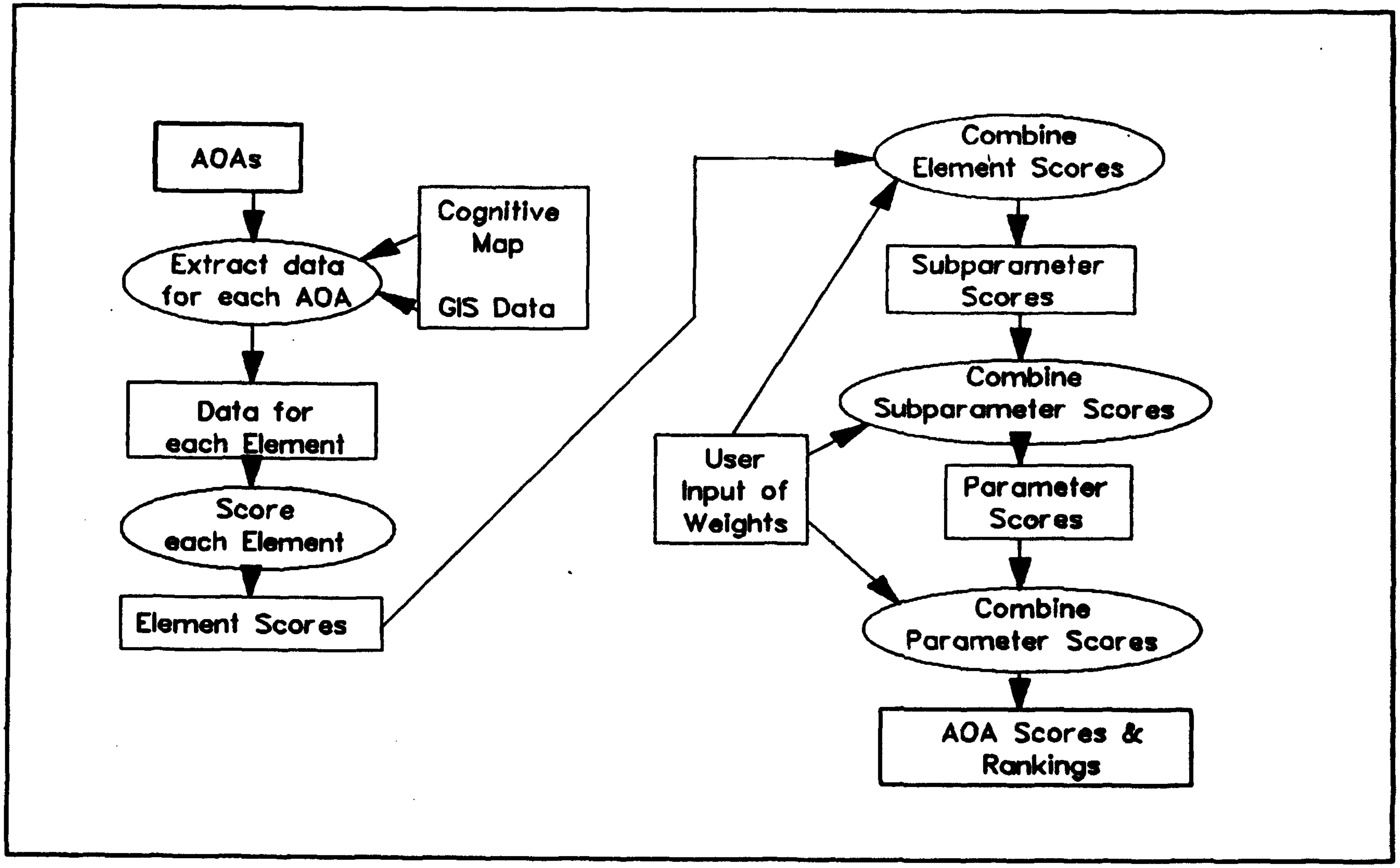
AOA Analysis Factors

- Observation and Fire
  - Attacker's overwatch and direct fire ability
  - Defender's observation and direct fire ability
- Cover and Concealment
  - Cover is protection from fire
  - Concealment is protection from observation
- Obstacles
  - Natural
  - Reinforcing (man-made)
- Key Terrain
  - Dominating terrain features
  - Important or necessary for mission success
- Adequacy of Maneuver Space
  - Freedom of movement
  - Chokepoints
- Ease of movement
  - Overall trafficability
  - AOA length and directness to the objective

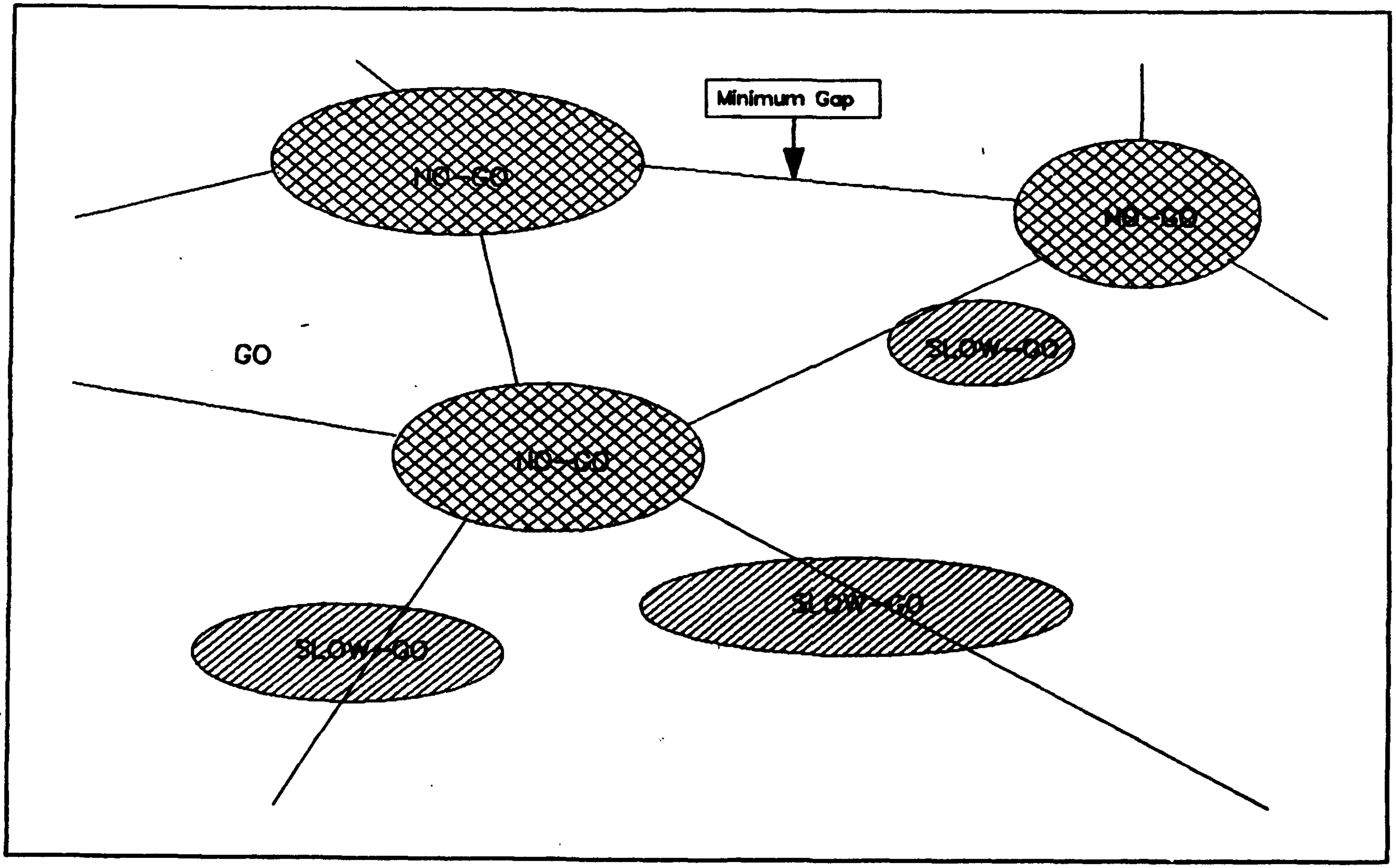
ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
Use of Terrain Data in AOA Compare



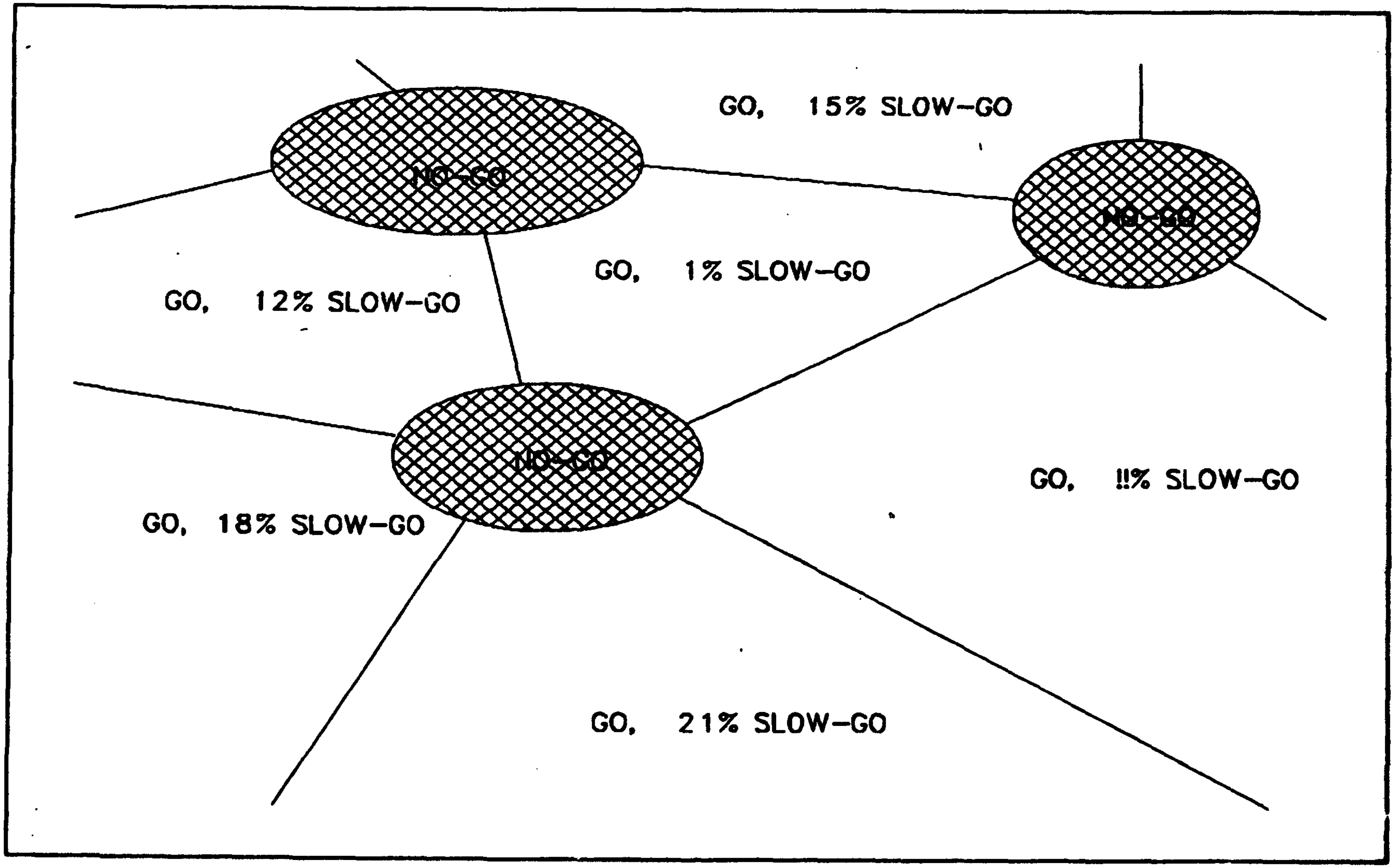
ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
The Process Used to Score and Rank AOAs



ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
Example of Minimum Gaps



ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
Example of Cognitive Map



ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
AOA Comparison Parameters

Avenue of Approach
Parameters
Subparameters
Elements

Vulnerability
- Observation
  - Percent Forested
- Cover & Concealment
  - Standard Deviation of Elevation
  - Standard Deviation of Slope Downhill
- Overhead Concealment
  - Average Vegetation Cover

Maneuver Space
- Available Space
  - AOA Area
- Canalization
  - Average Gap Width
  - Minimum Gap Width
- Choke Points
  - Percent SLOW-GO

Transit Time
- Off-Road Speed
  - Cross Country Mobility Speed
- On-Road Speed
  - Road Count
- Total AOA Length
  - AOA Length
- Average Speed
  - Average Speed

Ease of Movement
- Trafficability
  - Average Surface Mat. Roughness
  - Average Vegetation Roughness
  - Percent of Slope over 5%
  - Percent of Veg. stem Diameter > 8 inch
  - Percent of Tree Spacing under 12 feet
- On-Road Speed
  - Road Count
- Obstacles
  - Obstacle Count

ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
User Specified Parameters

- The user may specify parameters in addition to those provided by the system
- The user must provide the scores of these parameters for each AOA
- Examples of such user-specified parameters are:
  - Overwatch
  - Reinforcing (man-made) obstacles
  - Key terrain
  - River crossings

Avenues of Approach Comparison
Element Description

Vulnerability			
Subparameter	Element	Description	Comment
Observation	Percent Forested	Percentage of **sampled** AOA terrain data that is forested	
Cover & Concealment	Standard Deviation of Elevation	Standard deviation of the elevation values for **sampled** AOA terrain data	
	Standard Deviation of Slope Downhill	Standard deviation of the slope vectors (amount of slope and direction of slope) for **sampled** AOA terrain data	
Overhead Concealment	Average Vegetation Cover	For **sampled** AOA terrain data that is forested with vegetation height over 12 feet, the average of the values for % canopy closure (non-forested areas or areas with vegetation height under 12 feet are included in the average, but with a value of 0% canopy closure)	

Avenues of Approach Comparison
Element Description

Transit Time			
Subparameter	Element	Description	Comment
Off-Road Speed	Cross Country Mobility Speed	Using the relative amounts of NO-GO, SLOW-GO, and GO terrain in the AOA, and the unopposed movement rates for mechanized forces from ST 100-9, the time, in hours, required to transit the entire length of the AOA	
On-Road Speed	Road Count	The number of road segments in the entire area of the AOA (a road segment is a single straight line of a connected series of straight lines that defines the road)	
Total AOA Length	AOA Length	The length of the AOA along the centerline from start to end	
Average Speed	Average Speed	The length of the AOA, divided by the time required to transit the length of the AOA	

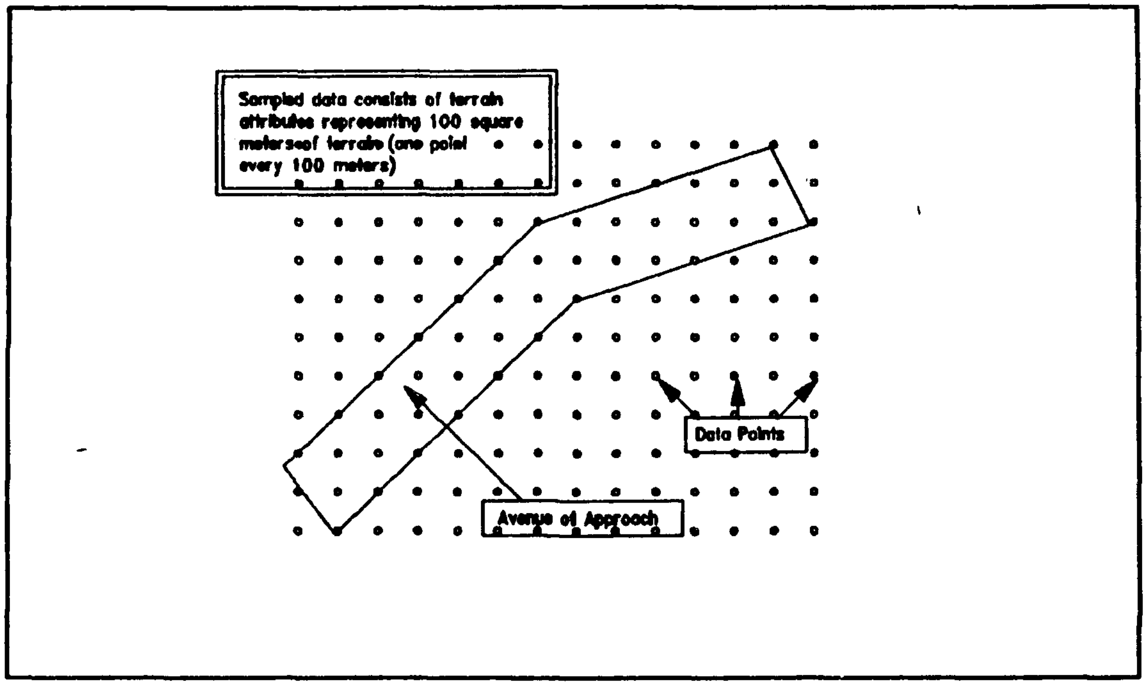
Avenues of Approach Comparison
Element Description

Maneuver Space			
Subparameter	Element	Description	Comment
Available Space	AOA Area	The computed area within the boundaries of the AOA	
Canalization	Average Gap Width	The average width of the AOA along its entire length	
	Minimum Gap Width	The minimum width of the AOA along its entire length	
Choke Points	Percent SLOW-GO	The percentage of the entire AOA area that is classified as SLOW-GO	

Avenues of Approach Comparison
Element Description

Ease of Movement			
Subparameter	Element	Description	Comment
Trafficability	Average Surface Material Roughness	The average value of Surface Material Roughness for sampled data within the AOA (values run from 0 to 1 as a multiplier of mechanized movement speed: a value of 1 means no degradation of speed due to the terrain surface, and a value of 0.8 means mechanized forces move at 80% of their normal speed)	
	Average Vegetation Roughness	The average value of Vegetaion Roughness for sampled data within the AOA (values run from 0 to 1 as a multiplier of mechanized movement speed: a value of 1 means no degradation of speed due to vegetation on the terrain surface, and a value of 0.8 means mechanized forces move at 80% of their normal speed)	
	Percent of Slope over 5%	Percent of sampled data in the AOA that has a slope of more than 5%	
	Percent of AOA with Vegetation Stem Diameter over 8 Inches	Percent of sampled data in the AOA that has stem diameters of more than 8 inches	
	Percent of AOA with Tree Spacing less than 12 Feet	Percent of sampled data in the AOA that has tree spacing less than 12 feet	
On-Road Speed	Road Count	The number of road segments in the entire area of the AOA (a road segment is a single straight line of a connected series of straight lines that defines the road)	
Obstacle	Obstacle Count	The number of individual obstacles the lie partially or wholly within the AOA, or that pass through the AOA	

ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Comparison
Sampled Terrain Data Intervals



Example Coverage of AOAs by Sampled Data

Echelon	Length (km)	AOA Width (km)	Area (sq km)	Total Data Points	Sample Points	
					Area represented for each sample point (sq km)	Data points represented by each sample point
BN	15	1.5	22.5	2,250	0.225	22.5
BDE	50	4	200	20,000	2	200
DIV	100	10	1,000	100,000	10	1,000

APPENDIX B

QUESTIONNAIRE RESPONSES

Appendix B-1

Responses to the Questionnaire Item, "Is this element description acceptable?"

Parameter	SubParam	Element	SME A Yes	SME A No	SME A Can't Jud	SME B Yes	SME B No	SME B Can't Jud	SME C Yes	SME C No	SME C Can't Jud	All SMEs Yes	All SMEs No	All SMEs Can't Jud
Vulnerability	Observation	% Forest	X				X		X			2	1	
	Cover & Concealment	SD Elev	X				X				X	1	1	1
		SD Slope		X			X				X	0	2	1
	Overhead Concealment	Ave Veg Cover	X			X				X		2	1	
Transit Time	Off-Road Speed	Cross Country Mobility	X					X	X			2		1
	On-Road Speed	Road Count	X				X		X			2	1	
	AA Length	AA Length	X			X			X			3		
	Ave Speed	Km/hr	X				X		X			2	1	
Maneuver Space	Available Space	Sq Km	X				X		X			2	1	
	Canalization	Ave Gap Width	X				X		X			2	1	
		Min Gap Width	X				X		X			2	1	
	Choke Points	% SLO-GO	X				X		X			2	1	
Ease of Movement	Trafficability	Surface Rough		X				X	X			1	1	1
		Veg Rough		X				X	X			1	1	1
		Slope over 5%		X			X				X		2	1
		Stem Diam over 8"	X				X				X	1	1	1
		TreeSpacing < 12'	X				X				X	1	1	1
	On-Road Speed	Road Count	X					X	X			2		1
	Obstacles	Count	X				X			X		1	2	
			15	4	0	2	13	4	12	2	5	18	16	9

Appendix B-1
(continued)

Responses to Questionnaire Item "Is this element description acceptable?"

Parameter	Sub-Parameter	Element	Written Comment
Vulnerability	Observation	% Forested	B: Also affects Cover & Concealment. Location of forest is more important than the percentage. Need to support fields-of-fire with line of sight. C: Need line of sight data and relief data (ridge lines).
	Cover & Concealment	Std Dev of Elevation	A: Hard to see relation of this to C & C. B: Also affects Observation. Location is more critical than percentage.
		Std Dev of Slope Downhill	A: Hard to see relation of this C & C. B: Also affects Observation. Location is more critical than percentage.
	Overhead Concealment	Average Vegetation Cover	C: Need to consider seasonal data.
Transit Time	Off-Road Speed	Cross Country Mobility	B: Movement rates need to be adjustable. The titles of the element and subparameter should reflect time, or duration, rather than speed.
	On-Road Speed	Road Count	A: No trails or other consideration is a shortfall. B: Need types of roads, road network, cross-compartmentalization data, and quality of terrain adjacent to the roads. Roads paralleling the AA are moreimportant for speed, roads crossing the AA inhibit speed, but provide movement flexibility.
	Total AA Length	AA Length	
	Ave Speed	Average Speed	B: Movement rates need to be adjustable.

Appendix B-1
(continued)

Responses to Questionnaire Item "Is this element description acceptable?"

Parameter	Sub-Parameter	Element	Written Comment
Maneuver Space	Available Space	Available Space	A: Length of an AA is not a consideration of Maneuver Space. Ability to move to the side (across the width) is the important consideration. B: More important at deployment lines and at the end of AA than at the beginning. Need to know mobility corridor space at critical points along the AA.
	Canalization	Average Gap Width	B: Same as above. Location and degree are critical. Need to know how many times, the degree, and the duration of canalization.
		Minimum Gap Width	B: Same as above. Location and degree are critical.
	Choke Points	Percent SLO-GO	A: Choke points are very narrow points along the AA (bridges, natural narrowing). B: Why use SLOW-GO as a factor? Location and degree are critical. Choke points are short, but extreme, restrictions of movement.

Appendix B-1
(continued)

Responses to Questionnaire Item "Is this element description acceptable?"

Parameter	Sub-Parameter	Element	Written Comment
Ease of Movement	Trafficability	Ave Surface Material General Roughness	A: Non-doctrinal B: Depends on how well and to what degree weather is included. C: Need to add varying levels of wet/dry.
		Ave Vegetation General Roughness	A: Non-doctrinal B: Depends on how well and to what degree weather is included. C: Need to add varying levels of wet/dry.
		Slope over 5%	A: Non-doctrinal value, 30% slope is doctrinal. B: Use slope value that represents SLOW-GO.
		Vegetation Stem Diameter	A: Use doctrinal value. B: Better if used in combination with roads.
		Vegetation Tree Spacing	A: Use doctrinal value. B: Better if used in combination with roads.
	On-Road Speed	Road Count	B: Quality of roads is important. Need density of roads, not a count.
	Obstacles	Obstacle Count	A: Add rivers, bodies of water, man-made obstacles. B: Location and size of obstacles are more important than the count. C: Add man-made obstacles, and grade obstacles in degree of difficulty in crossing or bypassing. Count of obstacles is not meaningful. The location and class of bridges should be included.

Appendix B-2

Sampling Method Questionnaire Responses

Questionnaire Item	Choice	SME A	SME B	SME C
How adequate is this method for determining scores for use in AA comparisons?	Very inadequate			
	Inadequate		X	
	Somewhat inadequate			X
	Somewhat adequate	X		
	Adequate			
	Very adequate			
	Don't have enough information to judge			
How confident are you in the results of this sampling method?	Very confident, would use the scores without reservation			
	Confident			
	Somewhat confident			X
	Little confidence	X	X	
	Very little confidence			
	No confidence at all, would not use the results			
Written Comments		Depends on area of operation, e.g., desert of Saudi Arabia will provide high degree of confidence using "sampling method", vice Fulda area in Germany where deviations in slope can be extreme.	Inadequate when used to make an overall assessment. Factors are more important at certain points along the AA and at the end. The process would be more effective analyzing as segments. Sampling method is least effective when addressing points which would restrict maneuver.	Assumes homogeneous terrain to use averages. Math models need to be checked with real data.

Appendix B-3

Element Scoring Questionnaire Responses

Questionnaire Item	Choice	SME A	SME B	SME C
How much confidence do you have in the scores that are calculated using the ALBM ATTD procedure?	Extremely confident			
	Confident			
	Somewhat confident			
	Little confidence	X		X
	No confidence at all		X	
	Written comment	Must answer "so what" question. For example, if all avenues are close in all values except one, should highlight this.	Too great of a reward is given for too little of a difference. This is based on samplings and averages which do not take degree and placement into account for any of the factors.	Normalization of the scores accentuates the differentiation between actual values. For example, a value of 49 and 50 may be normalized as 1 and 0.

Appendix B-4

Weighting Procedure Questionnaire Responses

Questionnaire Item	Choice	SME A	SME B	SME C
How difficult was this rating procedure ?	Very easy			
	Easy			
	Somewhat easy			X
	Somewhat difficult	X	X	
	Difficult			
	Very difficult			
How much confidence do you have in the weights you have given?	Extremely confident			
	Confident			
	Somewhat confident	X	X	X
	Little confidence			
	No confidence at all			
Written comment		Needs commander's intent which will provide values, if not stated then implied. For example, if his intent is to quickly complete passage of lines and conduct pursuit or hasty attack, time may be the critical factor, if we want to perserve strength or cconduct infiltration, then vulnerability is key.	Individual subcomponents of great importance, even when heavily weighted, could become diluted by the end of the process. Everything still hinges on the analyst's abilities.	Needed more information on the enemy and friendly COA.

Appendix B-5

Overall Assessment Questionnaire Responses

Questionnaire Item	Rating	SME A	SME B	SME C
Would you use the results of this comparison procedure?	Mostly certainly			
	Probably			X
	Uncertain	X	X	
	Probably not			
	No			
	Can't judge			
	Written comment	Depending on final outcome on resolution of issues, but anything that provides more information is of benefit given time to review differences.	Not as a system. Certain aspects would be of use.	Current method manpower intensive.

AACT Overall Rating

Questionnaire Item	Rating	SME A	SME B	SME C
How acceptable is this method to you?	Very acceptable			
	Acceptable			X
	Somewhat acceptable		X	
	Somewhat unacceptable	X		
	Unacceptable			
	Very unacceptable			
	Can't judge			
	Written comment	Can use as a tool, but with knowledge of deviations from doctrine and exact definitions of each value.	Some parameters are incomplete. On some subparameters, elements "generalize" very specific data (see comments on location and type regarding obstacles).	

APPENDIX C

VERBAL COMMENTS OF PARTICIPANTS

Verbal Comments of Participants on Doctrine

SME A

- Soldiers are trained to use OCOKA as AA analysis factors.

- When using values (slopes, stem diameters, tree spacing), use FM values.

- Threshold values of measures should be standard, based on doctrine.

- What's their definition of vulnerability? I just don't know what it means. It's a non-doctrinal term and it's very confusing. If they had called the factors Observation and C&C I might have bought off on it. When you look at an AA you're always told to use the OCOKA factors. I just don't like the term vulnerability. Its a non-doctrinal term I've never heard of. I don't have any trouble with the vulnerability factors other than SD of down hill slope.

- Redo factors. Change Vulnerability to Cover & Concealment. Change Maneuver Space to Ease of Movement. Add obstacles, Rivers. We see it all the time - people try to reinvent the wheel. Just use OCOKA factors.

- The bottom line is - the factors used for AA Compare should be standard (by the book).

- The system is non-doctrinal. I have reservations about the parameters. Some of the elements don't support the parameters, e.g. vulnerability.

- Nowhere do I see Key Terrain indicated here. Besides Rivers is obviously missing.

- I don't like Average Surface Material Roughness and the Vegetation Roughness - those are non-doctrinal terms. I've never heard of them. I can't say to the Commander - oh, I'm sorry sir. The terrain is very rough for us, so we can't go in there.

- Need to add Man-Made Obstacles, Rivers, and Bodies of Water.

- For Trafficability, one element is Percent Slope > 5%. In doctrine, slope uphill for no-go terrain is greater than 45%. Under 30% is all go terrain. So if you're saying the slope is over 5%, what is that telling me? When you use values you should use the program values. Most of the places in the world are going to have a slope of more than 5 percent at any given time.

Verbal Comments on Doctrine (continued)

- Key Terrain is critical. It's something that should be added. But it has to be user entered; it's subjective.
- Overhead Concealment is normally part of C&C.
- Transit Time is all part of Ease of Movement.
- Add Line of Sight to C&C.
- To Obstacles add Man Made Obstacles.
- Call Vulnerability Observation of Fire. Why make something new called Vulnerability? Trafficability is Ease of Movement. On Road Speed is Ease of Movement.
- Graphics for AA should be doctrinal. The yellow and green grid shades don't make sense.
- If you're doing a product and it's designed to be taken out where the analysts are, it should look like what the commanders have had and expect to see. And if it doesn't do that then what we have is a toy for the analyst. But now he's got to take all that data and transfer it to a map sheet in order to give him something that he can use.
- The system should develop mobility corridors. But you can ask for all battalion size AAs. The division AAs should be combinations of the battalion AAs. So it does give you mobility corridors. An AA is nothing more than a combination of mobility corridors for the lower units.
- Some of the parameters and definitions are non-doctrinal. Either they're accepted by the army or we change our doctrine.

SME B

- Having the parameters laid out by OCOKA would be better. T[illegible] system presents a problem because the words don't mea[illegible] as is currently taught. For example, Trafficability means something different.
- In performing importance weighing, the names given to the variables mean a lot. In the case of this system, the meaning we ordinarily give to the parameter names is sometimes different from how they're defined using the elements. I had to look at the ALBM definition of the terms used, since they didn't match the normal usage of those words.

Verbal Comments on Doctrine (continued)

- Line of Sight data is important to alot of people - more than the Percent Forested.

SME C

- Why keep inventing new terms and new classifications?
- Why couldn't they just use OCOKA? We've got a set of doctrinal terms that describes what we want to describe, let's stick with them.
- There are two reasons why you'd want to change doctrinal terminology. One, there's a new activity or concept you want to describe. Two, there's a training shortfall. People don't understand doctrine so they continue to coin new terms to describe already identified activities. You're going to have guys who go through the terrain analysis course and then go out to the field and find a computer system that's different. Now they have to retrain that guy. That's the biggest problem with automation in the military. The guy learns in school how to do it all. He gets to the field and finds a new computer system that has a whole bunch of terminology that really kind of means the same thing but kind of different. You train on it, and when you leave the unit you never see it again. I believe the purpose of automation is to assist not hamper the analyst.
- This system changes doctrine - new terms and definitions. This creates a training problem for units, in that soldiers learn the terrain analysis framework in the classroom, and is then required to learn a new framework to use the system.
- The system is generally compatible with doctrine, except for terminology.
- Man Made Obstacles would be one of the things that you would add and score yourself.
- You know what I haven't noticed in all this is Bridges. Bridges are really key in assessing AAs. I haven't seen consideration of brides, type bridges, and weight classification of bridges. If you've only got class 30 bridges in your sector you're not going to be driving tanks across it. We now have a fatal flaw. You can't do an AA analysis without considering the bridging.
- The location and classification of bridges is important. River obstacles may or may not exist, depending on bridges.

Verbal Comments on Doctrine (continued)

- The purpose of reinforcing obstacles is to shape the battlefield.

- Average Surface Material Roughness probably depends on the weather. If it is excessively dry, it affects Cover & Concealment (dust). There is a linkage between weather and visibility.

- Line-of-Sight needs to be considered in Observation to meet doctrinal requirements.

- Average speed is helpful. User often make units go faster than they actually can go. CBS (Corps Battle Simulation) has a congestion model.

- Road Count doesn't meet the "so what" test.

- On-Road Speed is the wrong term. Road Count doesn't represent speed.

- In Germany there is no no go terrain for tanks. They go slow, but they go.

- I think AACT could suggest - this is a piece of key terrain based on line of sight and based on its dominance of the AA. It would appear to me that the data is available for the computer to make a suggestion of Key Terrain based on the line of sight from a particular obstacle. If you own this piece of terrain you control the AA. The analyst will go back and check those factors.

Verbal Comments on Elements, Subparameters, and Parameters

SME A

- I'm unsure of the validity and meaning of elevations and slopes as a measure of Cover & Concealment. Forested areas are important. For C&C I'm not sure I used Slope Downhill much at all. I've never heard of using SD of Slope for C&C. The SD of the Elevation is more important than slope for C&C. When the analyst analyzes C&C its primarily the Forest & whether he can be concealed. But primarily its just the differences between the elevations between the various pieces of terrain. I've never heard of C&C in terms of degrees of slope. I've never used slope as a factor in C&C. The only time I've ever used slope for C&C is determining the effect of slope on tank movement. I just don't understand SD of slope down hill as a factor of C&C.

- Don't understand why standard deviation of slopes is used to measure vulnerability.

- Need Line-of-Sight information to evaluate Observation and Fire.

- On-Road Speed is confusing. Trails should be considered, as well as hard surface roads. Need to know about high speed roads running along the AA.

- I don't like the definition of Choke Point as Percent Slow Go terrain. A Choke Point is something very defined. Its the point where the terrain comes together. Where the width of the corridor narrows. It has nothing to do with slow go terrain. Choke Points are defined in your terrain analysis FM and don't have anything to do with slow go terrain.

- Don't like Surface Material and Vegetation Roughness factors for AA analysis.

- The Transit Time elements provide Ease of Movement information.

- Available Space is not necessarily square km.

- Rivers should go into Ease of Movement.

- The only other thing I would add is your Objectives. These would be user specified.

- Maneuver Space is not necessarily the length. If two AA's have the same width but one is longer, it would be scored higher on Maneuver Space. It would give you a false impression.

Verbal Comments on Elements, Subparameters, and Parameters (continued)

SME B

- Rename Off-Road Speed to reflect time duration. Rename On-Road Speed to reflect counting of roads.

- In Canalization, I keep going back to where the gaps are. Where is it going to be canalized. Early for some short duration, that's one thing. But if it's later when you're close to the enemy, that would be a different story.

- For Obstacles, also need size, where it is, and how much it would decrease your ability to maneuver.

- For Trafficability, what's important is the degree of slope that could make it go from slow go to no go. It should be greater than 5 percent.

- Available space is critical at the end and its very important at the beginning. If we could cut the AA into segments and look at it that way instead of all of the available space. The commander thinks passage of lines and sees available space. If he has those two in his mind, he's not going to be thinking - they're talking acreage within this AA. He's talking about how much room has he got to move through the other element. He'll say the most important thing in passage of lines - if we can't move through this force quickly to continue the attack we're done for. Hopefully he'll understand what they're talking about - that available space also include how long the AA is.

SME C

- Vegetation cover should be seasonal.

- The count of Obstacles is useless, unless the type of obstacle is known.

- Need to grade Obstacles in degree of difficulty in bypassing them.

- Does any of this consider air AAs? Observation isn't really adequately measured by Percent Forested. For Observation you need Line of Sight. All the relief factors need to be figured into Line of Sight.

Verbal Comments on Scoring of Elements

SME A

- Scoring is meaningless if the data values are close. Somehow, system has to show where significant differences exist between AAs. System doesn't answer the 'so what' question.
- The system doesn't show what are significant differences in the data.
- Have system display a data matrix. User should be able to select significant differences for further analysis. Have to know data values in order to make importance ratings.
- Should color code top parameters. Close values should be the same color.
- You should be able to pull up the data to find out if the differences are significant. I'd like something that would give me significant differences. Something I could key on in a flash. The system has to be able to show me the significant differences between the avenues. That's the thing that makes me determine what to brief the old man on. If I had this, I'd ask the system to print out a page and then I'd get a yellow highlighter and highlight those significant differences.

SME B

None

SME C

- Scoring should occur when significant differences exist between AAs. Where data is pretty much equal, this scoring method could be misleading.
- The scoring system accentuates differences.
- Because of the normalization method used in scoring, AAs may look more different than they are.
- Need a way to backtrack to look at the raw numbers. You may get a green color coding which will look significantly better even though it's only minimally better. Maybe there ought to be some measurement that says a color difference is greater than 10 percent.
- I think there needs to be some range where the scores are equal. When you're doing sampling that area may be larger than if you were measuring every point in the ground.

Verbal Comments on Scoring of Elements (continued)

- You'll find the commander wanting to see the actual raw data because he doesn't trust the system because he found out that the differences were not that great in one instance.

Verbal Comments on Weighing of Importance

SME A

- I like the option that you can assign weights. But how useful is it under the circumstances? The commander is only interested in in for example, that maneuver spaces is weighted more than ease of movement. He doesn't get involved in the other stuff. I'd go back to the old pluses and minuses. Just add up the pluses and the one with the most wins. Or Rank them and multiply them by the rank.
- Could be that one or two critical points will wipe out an AA.
- One always likes to have the option to get more detail than +'s and -'s.

SME B

None

SME C

- For weighing, need to track back and look at the numbers. The mathematics may be hiding the actual effects.
- Need more information to make weight judgements.
- The second method was easier for me. It was more apparent to me how the factors fit.

Verbal Comments on Data Sampling

SME A

- The validity of sampling method depends on the variability of the terrain, where you are on the terrain.

SME B

- If the trees are all in the first half of the avenue and it's bare ground the rest, that's different than having trees scattered evenly along the whole way. But you come out with the same number in both cases. You should just not look at the amount but where it is. How sparse, how together it is and the distribution of it across the avenue. But it still wouldn't tell you whether it was at the front or back. You should also have the map to look at. I'll just put it down as a problem.

SME C

- The underlying assumption is that the terrain is homogenous. If it's homogeneous, the sampling technique might work here. Also depends on how big your area is. Particularly at Corps level, you're less apt to have homogeneous terrain the larger your avenue becomes.

- The results of the data sampling method depends on how big an area is being sampled.

Verbal Comments on Terrain Data Base

SME A

- You have cross-country mobility only for mechanized forces. Need data for other forces.
- Cognitive map doesn't show where the SLOW-GO is. SLOW-GO is critical -
  - Where's a unit going to get slowed down?
  - Commander wants to know where SLOW-GO is.
- Use of urban areas as NO-GO must be done carefully.
  - Small village in middle of AA is insignificant.
  - Frankfort is a major obstacle.
  - Need to look at NO-GO in terms of doctrinal definitions.
  - All urban built-up areas are not necessarily NO-GO.
  - It's sometimes a subjective call when built-up areas are NO-GO. For example, one small village might be GO, while several neighboring villages might be NO-GO.
- How is NO-GO terrain determined?
- River crossings should be in the data base.

SME B

None

SME C

- The underlying terrain data base needs to be regularly updated to account for growth.
- In Germany there is no NO GO terrain for tanks. They go slow, but they go.

Verbal Comments on Overall Design

SME A

- Need mobility corridors.
- Mobility corridors should be developed and drawn. But this is what you get if you draw AAs one level down.
- Factors may change depending on mission, terrain, weather, enemy, etc.
- For ease of movement use:
  - Space to maneuver - canalization
  - Obstacles
  - Roads
  - Is it wide enough?
  - Length - only in macro sense. Does it get narrow?
- Key Terrain is critical, and should be included in the set of variables to be considered by the user.
- Need to consider Man-Made Obstacles and Key Terrain.
- Some items are considered a number of times.
- Would be useful to show data matrix and color code significant items. Need to be able to brief "Why it came out that way". Commander doesn't need the numbers; analyst needs to know the numbers.
- AAs are normally drawn with arrows, and in red or green(?) colors.
- The intel user needs access to detail, summary data is for the commander.

SME B

- Mobility corridors are more important than the representation of the AA.
- Cross compartmentilization of mobility corridors is important, in that they negate the effect of obstacles.

Verbal Comments on Overall Design (continued)

- The system should know the needs of the echelon concerned. Even if the system was perfect in data analysis, it should rely on the user for input and adjustment. The person would have to know how to do the analysis very well without the system in order to make the adjustments.

- The ability to process terrain data will save a huge amount of time, if the system could break the AA into segments.

SME C

- What worries me is that someone who's using this must understand what assumptions you've made.

- No go and slow go terrain is dependent on the force. Light infantry has essentially no no go terrain. It would be really nice if the G2 is able to set the parameter of type of forces.

- For cross country mobility, should have the ability to adjust movement rates.

- Key terrain should be part of the system. It is based on line-of-sight.

- There should be an easy way for the user to do sensitivity analysis; why the figures came out the way they did. Must be able to tell the commander what the driving factors are that recommend an AA. There is a need to know which variables were key in determining the results. This would also tell how to make changes to make one AA the best.

- Mobility corridors are used at battalion and brigade echelons. They are not a big requirement at division or corps.

- On overlays, choke points are marked in red.

- Add ability to determine impacts on AA of adding obstacles.

- I like the idea of being able to draw your own AAs. Because a lot of guys would like to speculate those little 'what if' tasks. If the enemy came through here how long would it take him?

- There ought to be the capability to adjust movement rates as part of the menu. One of the things you do after the AA analysis is build time phase lines for your event template. Say I would expect them to move unopposed this far. Then they'll hit the covering force and I would adjust the rate to 5 km per hour. This will help complete the AA analysis.

Verbal Comments on Overall Impressions

SME A

- The system can be used as a guide, and to supply details on NO-GO and GO terrain.
- I'd use the system as a tool rather than to get a magic answer. I don't trust the machine to that for me. The system would be worth using because anytime you can get a machine to do the same thing I have to sit at a stubby pencil drill. Drawing slow go and no go terrain can be very labor intensive.
- I don't know if this system does a good job of comparing.
- If ALBM is drawing a product, it should look like what the commander expects to see. What you have now is a toy for the analyst. Now what you have is something you have to transfer to a map before you can show it to the commander.
- Need to compare a manual AA comparison with the AACT Comparison to determine validity.

SME B

- Would probably use the system for certain pieces of it, because I would know how I could do things to get at the data I wanted.
- If I were to use the system now, it would be for the access to terrain data, and for the graphics.

SME C

- I don't know if the mathematics of the method models "real world".
- I would probably use the results of this because the current way to do it is so manpower intensive. It's so manpower intensive that you end up with it being on art right now as opposed to a science.
- Like the idea of drawing an AA to do 'what if' analysis. Otherwise, would analyze only the obvious AA.
- The purpose of automation should be to assist the user, not do the job for him.

Verbal Comments on Overall Impressions (continued)

- One thing I really worry about is keyboard proliferation. You go into a command post and they've got 16 different computers and a guy has to know 16 different sets of commands. Let's try to implement it through software on an existing system. If this runs on standards like MCS, that's great. That's where it ought to be.
- The system could be used to build event templates.
- Q. How long would you wait for an answer? A. Right now it takes 6-10 man hours. I don't see any reason why 30-40 minutes in processing time would be unacceptable.

APPENDIX D

DECISION ANALYTIC CRITIQUE OF AACT

Appendix D

MEMO

To: Dr. Sharon L. Riedel
From: Dr. Leonard Adelman
Topic: Decision Analytic Critique of AACT
Date: July 14, 1992

This memo presents a short decision analytic critique of the Battlefield Area Terrain Advisor' (BATA) within ALBM-ATTD. The critique is based on a demonstration of BATA given on 6 July 1992 at the Future Battle Lab (FBL).

The memo has three parts. The first part addresses BATA's weighting procedure, which is incorrect given the relative scaling procedure used to score values on the bottom-level attributes (called "elements") in BATA's multi-attributed hierarchy. The second part addresses BATA's scaling procedure which, when there are more than two alternatives ("Avenues of Approach"), creates only linear functions. The third part addresses the redundancy in the hierarchy, which can lead to the double-counting of certain "elements;" specifically "On Road Speed".

Each part is considered, in turn. Before proceeding it important to note that all three problems referenced above, and discussed below, can result in BATA suggesting conclusions that are inconsistent with a planner's own position. The memo identifies general fixes for each problem, but does not provide specific recommendations, for that depends on the desired direction of the development team and user community's representatives.

1. Weighting Procedure

BATA uses the concept of importance weights. However, it should be using the concept of "swing weights" instead. This is because it is using a relative scaling approach where the best alternative on an attribute is given the highest value on that scale (e.g., 1.0) and the worst alternative is the given the lowest value (e.g., 0.0). In such a situation, one wants to know the relative importance of the difference (or "swing") between the worst and best alternatives on the attributes, not the general importance of the attributes. We will provide a simple example showing how one can arrive at incorrect results if one uses "general weights" instead of "swing weights". First, however, we provide a quote from Watson and Buede (1987, pp. 200-201) that further discusses the difference between importance and swing weights.

"Before describing these two elicitation procedures, let us first acquaint the reader with the difference between importance weights and swing weights. Importance weights are used to reflect the general importance of one attribute over another, without regard to the particular decision application, or, more specifically, the difference between the worst and best value points of each attribute. When this differences from worst to best is not explicitly referenced in assessing weights, we obtain some general notion of importance, which is subject to great variation and argument among decision-makers. The correct concept of value weight is the swing weight, in which the decision maker is explicitly comparing the swing in value (worst to best) of the attributes in question. These weights reflect well-defined quantities, and the decision-makers can have meaningful discussions about what their values should be. The swing weight should also be changed when the range from worst to best for a given attribute is changed. (Throughout the remainder of this book, the swing weight concept will be implied when the word 'weight' is used in a value sense."

A simple example can be used to show how using importance weights instead of swing weights can arrive at different conclusions. Assume that a person has to decide between two jobs on the basis of two attributes: salary and location. (All other factors are equal.) Let's assume further that, in general, salary is more important than location; that is, salary has a (general) relative weight greater than 50 (on a 0 to 100 percentage scale), and location has a (general) relative weight less than 50. However, in this particular case, Job #1 pays only $25/year more than Job #2. In contrast, Job #2 is in a highly attractive location to the decision maker, whereas Job #1 is in a highly unattractive location. If a decision aid used general importance weights and a relative scaling approach, like BATA does, it would recommend Job #1 because (a) Job #1 gets a score of 1.0 on salary (Job #2 got a score of 0.0), and (b) salary has a weight greater than 50. In contrast, Job #2 would almost certainly be selected if one used swing weights, for the difference in $25/year salary in trivial compared to the difference in living in a highly attractive versus unattractive location, all other factors being equal.

It is important to note that one can remove the inconsistency in the conclusions by using (a) general importance weights, and (b) an absolute scaling approach instead of a relative scaling approach. With an absolute scaling approach, one creates a scale going from the lowest to highest conceivable (or practical) values for each attribute. Then, in contrast to the relative scaling approach, the alternatives are scored directly onto the scale instead of giving the best scoring alternative the highest score and the worst scoring alternative the lowest score. The scores on the absolute scale are then converted into utility scores based on the utility function for the attribute. In the job example, the absolute scaling approach would have caused the two jobs to be scored very close together on salary and very far apart on location. Consequently, when one multiplied the utility scores by the weights, Job #2 would have had the highest overall utility score.

In sum, the critical point is that BATA has to use consistent weighting and scaling approaches to avoid the possibility of arriving at contradictory conclusions. If it uses a relative scaling approach, then it has to obtain swing weights from the users. In order to do so, BATA would have to (1) make clear to users that they are providing swing weights, (2) systematically show users the actual "worst" and "best" scores on the "elements" so that users can specify the relative importance of these differences (or swings), and (3) incorporate procedures for obtaining the swing weights at the subparameter and parameter levels of the hierarchy.

In contrast, if BATA is going to use general importance weights, then it needs to use an absolute scaling approach. Ironically, BATA already employs absolute scales at the element level because all the scales are defined in terms of quantitative values, such as percentages, standard deviations, averages, and numbers. The absolute scales are changed into relative scales by giving the best scoring alternative a score of 1.0 and the worst scoring alternative a score of 0.0. I do not know why this was done. One reason may be that it is difficult to define the endpoints for some of the elements, which it necessary when using absolute scales. This problem seems surmountable, however, based on the demonstration of BATA given to me. In any event, consistency in the weighting and scaling approaches is essential for avoiding the possibility at arriving at contradictory conclusions.

I want to make two final points here. First, even when using an absolute scaling approach the users need to know the range of scale values on the bottom-level attributes prior to providing their importance weights. This ensures that all users are providing general importance weights that are tied to the scales used in the MAUA.

Second, it would help users to see the actual utility scores without requesting the explanation capability. This is necessary when providing swing weights for the elements. In addition, the presentation of the utility scores at all levels of the hierarchy, but particularly at the top, would help users assess how close or far apart the AOAs are on the attributes. Although the colored gumballs give a visual image as to which AOA is best, they do not indicate how much better one alternative is than another or if the difference is great enough to make much of a difference. It is quite possible for one AOA to have a minimally higher overall utility score than another, for the first AOA to get the green gumball, and for the user to conclude that the two AOAs are essentially tied after looking at the overall utilities. Consequently, either (a) the utilities also should be presented to ensure that users do not arrive at inconsistent conclusions by only seeing the gumballs or (b) some other symbol (e.g., an asterisk) should be provided at the top of the hierarchy to indicate that the difference between the top two alternatives is so large that users can be confident in the overall conclusion, given the weights and scores, without seeing the utilities.

2. Linear (Utility) Functions

We put the word "utility" in parentheses because it is important to note that two scoring concepts are inherent in any MAUA scaling approach. The first concept is that of scoring alternatives on an attribute's natural scale. This first concept is represented by the example of scoring the two job alternatives on a salary scale. The second scoring concept is that of converting scores on an attribute's natural scale onto a utility scale. For example, independent of the relative importance placed on salary, most people think that a larger salary has more utility (or "value") than a smaller salary. The exact shape of the utility function converting salary into utilities depends on the person. For some people a small salary increase may have alot of utility; for others, it might take a large salary increase; and others might have a straight linear function relating salary and utility. The critical point here is that there is a second concept (and step) when considering "scoring;" that is, obtaining utility scores. This second step converts the different natural scales, the "apples and oranges" represented by, for example, "percent forest" or "average vegetation cover," onto a common utility scale.

The absolute scaling approach distinguishes between the two scoring steps. The relative scaling approach combines them by giving the best scoring alternative a utility score of 100 and the worst scoring alternative a utility score of 0 on the attribute. This is not "bad," it just has a number of implications, such as using swing weights. For example, it also means that the utility scales are tied to the set of alternatives (AOAs) used in the analysis. If a new AOA is added to the set, or if an old one is dropped, such that the best AOA or worst AOA on an element changes, then one needs to obtain new swing weights.

It is also important to point out that BATA creates only linear utility functions when there are three or more AOAs. This is because it proportionally calculates the (utility) value of the AOA that falls in between the best and worst AOA on an attribute. For example, if AOA #2 has a value on an element that falls exactly in between that for AOA #1 and AOA #3, AOA #2 will get a 0.50 on that attribute. This is not bad; in fact, it may well be the most reasonable thing to do without giving the user the opportunity to create a utility function that converts scores on the elements into utility scores. Moreover, the design team may have discussed this point and decided that it was too complicated to let users specify utility functions interactively using BATA. However, it is important to note here, as part of this requested critique, that users might want to employ nonlinear utility functions for certain elements, subparameters, and parameters. Just as in the salary example presented above, users might want to indicate that being 50% on the natural scale for a particular element translates into a 10%, 30%, 80%, etc. score on the utility scale.

If a large percentage of nonlinear functions are used, then it is possible to obtain different results for the same set of swing weights. Linear functions are quite robust, however; consequently, it typically takes big differences in the utility scores (due to different functions) on important attributes to result in different conclusions. Therefore, before proceeding to implement a new module to permit users to specify utility functions, which will be difficult for users to do interactively, I would recommend assessing (a) the sensitivity of the AOA conclusions to the type of utility functions, (b) whether users would want to generate utility functions for the attributes in BATA and, if so, (c) whether they could easily and reliably do so.

3. Redundancy in the Elements.

"The definition of non-redundant attributes is that a set of attributes provides non-overlapping measures of the alternatives being considered (no double counting)" (Watson and Buede, p. 192). The basic idea is that an alternative that scores well on an attribute shouldn't get an unfair advantage because the same (or a highly similar) attribute is included in the MAUA hierarchy more than once. "Non-redundancy" is one of the five criteria for a well structured hierarchy originally proposed by Keeney and Raiffa (1976) in their seminal book on MAUA.

The terrain hierarchy in BATA has some redundancy because "On Road Speed" is included twice: once as a subparameter for assessing "Transit Time" and once as a subparameter for assessing "Ease of Movement." (Note: Since "On Road Speed" is measured by only one element, "Road Count," "On Road Speed" is essentially an element in the hierarchy.) In addition, the version of BATA demonstrated to me did not have scores for two elements: "Available Space" and "Canalization." As a result, there are only thirteen different elements in BATA and one of them ("On Road

Speed") gets relative weights twice. This certainly appears to be a situation where the AOA that scores best on "On Road Speed" gets an unfair advantage.

One procedure for minimizing the relative weight given to "On Road Speed" is to show users the cumulative weight given to the thirteen elements, and to permit them to modify them if they seem inappropriate. The cumulative weight is obtained by multiplying the relative weights from the top to the bottom of the hierarchy; consequently, it is the total (or cumulative) percentage weight given to each element. By giving users an opportunity to view and modify the cumulative weights on the elements, they might be able to counteract double counting on "On Road Speed."

A more fundamental issue is the level of redundancy in the entire hierarchy. When we discussed the double inclusion of "On Road Speed" during the demonstration of BATA, you mentioned that the developers said that the reason it was included twice was because the expert(s?) considered it necessary for assessing two parameters: "Transit Time" and "Ease of Movement." Yet, on the surface, these parameters seem highly redundant, for the easier it is for units to move, then the better their transit time. Moreover, "Transit Time" has only two subparameters: "On Road Speed" and "Off Road Speed." The former is already included in "Ease of Movement." If one also included "Off Road Speed" in "Ease of Movement," then one could eliminate the "Transit Time" parameter, the double inclusion of "On Road Speed" and, in turn, the redundancy in the hierarchy. This would improve the hierarchy, the relative importance weights, and the MAUA; in short, the aid.

References

Keeney, R.L. and Raiffa, H. (1976). Decision With Multiple Objectives: Preferences and Value Tradeoffs. New York: Wiley.

Watson, S.R. and Buede, D.M. (1987). Decision Synthesis: The Principles and Practice of Decision Analysis. New York: Cambridge.

APPENDIX E

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

Appendix E

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AA	Avenue of Approach
AACT	Avenue of Approach Comparison Tool
ALBM	AirLand Battle Management
AMC	Army Materiel Command
ARI	Army Research Institute
ATCCS	Army Tactical Command and Control System
ATD	Advanced Technology Demonstration
BA	Battlefield Area
BCBL	Battle Command Battle Laboratory
C&C	Cover and Concealment
CCM	Cross Country Mobility
CECOM	Communications and Electronics Command
COA	Course of Action
DMA	Defense Mapping Agency
EM	Execution Monitor
ESC	Enemy Situation Capabilities
ETL	Engineering Topographic Laboratory
FITE	Force Interactive Tactical Evaluator
FLC	Force Level Control
FM	Field Manual
FSC	Friendly Situation Capabilities
ITD	Interim Terrain Data
MAUA	Multi Attribute Utility Analysis
MCOO	Modified Combined Obstacle Overlay
MCS	Maneuver Control System
MET4	Mission, Enemy, Terrain, Troops and Time Available Tools
OCOKA	Observation and Fire, Cover and Concealment, Obstacles, Key Terrain, Adequacy of Maneuver Space
OPORD	Operations Order
PEO-CCS	Program Executive Office for Command and Control Systems
SD	Standard Deviation
SME	Subject Matter Expert
TDA	Tactical Decision Aid
TRADOC	Training and Doctrine Command