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Guide for Reviewers of Studies Containing Cost-Effectiveness Analysis

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(Distribution of this Unedited Draft has been authorized at this time only for the purposes of securing comments)

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FOREWORD

Logical methods of problem solving which take into consideration both the relative cost and effectiveness of alternatives have been accepted military staff procedure for many years. However, the rapid advances and increased diversity in technology since World War II have increased both the range and complexity of alternatives in weapons systems and organizations to carry out the military policy of the United States. The difficulty of selection has been compounded by the high costs of technological developments and the limitations of peacetime budgets. To assist in these increasingly difficult choices, development of more useful and effective tools has been required.

The Research Analysis Corporation is engaged in a series of studies aimed at the continued development of tools and teaching aids to assist the Army in performing and evaluating studies containing the analysis of alternatives. As one step in this research, we have prepared a tentative guide which may be of use in reviewing and evaluating these analyses. Those who are relatively familiar with cost-effectiveness analyses may find the Guide useful as a convenient checklist. To the less experienced man it may serve as an elementary text. In its preparation, we drew not only on our own experience, but on that of many scholars and soldiers. We particularly wish to thank Col. John Newman and the members of his Systems Analysis Division of the Office of the Chief of Staff, US Army, for their assistance and patience in helping our analysts with many concepts and problems. We also wish to thank Col. James Hayes of the Office of the Deputy Assistant Secretary of Defense (Systems Analysis) for his helpful suggestions.

In addition to the stated authors, many members of the Research Analysis Corporation contributed to the preparation of this Guide. In particular, the Guide benefited from the contributions and suggestions made by Mr. Arnold Meltsner, Dr. Edward Berman, and Mr. John Phillips. The document was reviewed by Dr. George Pettee, Dr. John Hardt, and Mr. Roderick Dennehy. Their comments were very helpful. The responsibility for the contents rests with the stated authors.

Many of the problems raised in the Guide require a fuller discussion than appropriate to this document. We are in the process of developing more complete guides to significant aspects of cost-effectiveness analyses for those who will have the need to work with them. For example, one of the guides in preparation will treat the role of the threat in cost-effectiveness analysis; another is an introduction to military cost analysis.

These guides need to be improved, particularly by the insights of those who will be using them. All comments and suggestions will be gratefully received and should be sent directly to the Research Analysis Corporation, Economics and Costing Division, McLean, Virginia, 22101.

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Chapter I

GENERAL BACKGROUND

Introduction

To assist in the review of studies containing cost-effectiveness analyses, a series of key questions with explanatory notes have been prepared and are contained in the next chapter. These questions, taken together, will not necessarily cover all aspects of all cost-effectiveness analyses. No one general list of questions can do that. Rather, the questions are designed to focus the attention of the reviewer on selected aspects to assist him in evaluating the analysis. All the questions are not applicable to all studies and they are not necessarily of equal importance to those studies where they do apply. The reviewer must exercise his judgment on whether the questions are applicable and the degree of applicability to the study being reviewed. Those questions that are considered particularly important and of widest application have been underlined, and are also listed separately for convenience in the back as "SELECTED QUESTIONS."* This document is intended only as a guide and not as a full and comprehensive treatment of all aspects of cost-effectiveness analysis.

Questions that do not bear on military cost-effectiveness analyses are not included in the next chapter. Furthermore, no questions are addressed to the subject of the intuitive judgment and other factors used in making decisions to which cost-effectiveness analyses contribute.

Cost-Effectiveness Analysis and the Estimate of the Situation

Cost-effectiveness analysis is a method for studying how to make the best of several choices. By cost-effectiveness is meant the relation of the resources required (cost) to achieve a certain ability to accomplish an objective (effectiveness). The term cost-effectiveness is always used in relation to the effectiveness of alternative systems, organizations, or activities.

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*Questions 1, 4, 12, 13, 14, 22, 23, 31, 37, 44, 46, 57, 60, 66, and 73.

Cost-effectiveness analysis is based on the economic concept that all military decisions involve the allocation (best use) of limited resources among competing requirements. The allocation is determined by studying how to get the best use of the available resources. This same concept is embodied in Army decision processes. It is used by a combat commander when he determines (estimate of the situation) the allocation of his resources (forces) among the main and secondary efforts and reserves in the offense or between the forward and reserve forces in the defense. A G3 uses the same concept in preparing his recommendations for reallocating, among the elements of the command, the ammunition available supply rate announced by the higher headquarters. The company commander goes through the same process in deciding how to spend his company funds.

Although cost-effectiveness analysis and the estimate of the situation are similar in concept, they differ in several aspects. The purpose of an estimate of the situation is to arrive at a recommended course of action. It is usually a process to arrive at decisions to solve "today's problems today." It does not concern itself, in a realistic sense, with problems, operations, or systems of the future, even though it is sometimes not clear where the problem of today ends and the problem of tomorrow starts. Because it deals with relatively immediate problems, the formulation of possible courses of action in an estimate of the situation is severely limited. The resources (forces and weapons) available to the commander are fixed by what has been made available and there is no real flexibility in changing their composition or basic organization. In practice, it is also usually difficult to obtain additional resources from the next higher commander.

Another severe constraint on the estimate of the situation is the time factor. Information is usually incomplete and the time available before a decision is required often does not permit filling in gaps--even if it were possible. Often there is only sufficient time to analyze the mission, gather staff estimates, formulate a few possible courses of action and quickly weigh these courses of action against the enemy capabilities (or difficulties to be overcome) and with each other, and select a course of action based on some criteria--often called the governing factors. Time usually does not permit testing the range of the dependence of the proposed course of action on the staff estimates and planning assumptions.

Military cost-effectiveness analysis is not a decision process but an aid in facilitating decisions that must be made now in regard to development, force composition, and logistical and manpower policy problems in order to be prepared for wars in the future. The analytical techniques employed in cost-effectiveness analysis are required to supplement those employed in the estimate of the situation because, as we look into the future, the number of uncertainties multiply. These uncertainties include such things as planning factors, the enemy and his reactions, the strategic concept, technology, chance, and even the national objectives which can be expected to change in the future as alliances shift and new forces in the world develop. Advances in technology create new opportunities that may require changes in organization and doctrine as well as hardware. All these uncertainties lead to a large number of variables that must be considered. Some of these variables are subject to our control, some to the enemy's and others to nobody's control. But all are variables, and all are interdependent.

The increase in numbers and kinds of variables associated with problems of the future can be illustrated, on a small scale, in a hypothetical study of a future weapons system for an infantry platoon--assuming that the infantry platoon will be present in the time frame under consideration. The variables that would require study would include such parameters as alternative weapons systems that can be available in the time frame under study, composition (mix) of kinds of weapons within the total system, the number of individual weapons within each mix of weapons, levels of warfare, expected locales of war, and effects of supporting weapons of higher echelons. If each of these parameters takes only three alternative values; for example, levels of warfare to be considered are nuclear warfare, conventional war, and one type of stability of operations, over 700 cases result--and all significant parameters have not been listed. If the number of candidate weapons systems is increased from three to six there are over 1400 cases to be considered.

It is in this environment of uncertainties and flexibility in use and interchangeability of resources (people, dollars, and hardware) that cost-effectiveness analysis is a useful aid. It assists in providing increased insight into the problem and as much relevant information as possible in order that the decision maker can concentrate on those areas where judgment must be applied, particularly in consideration of qualitative aspects and consistency with higher echelon considerations. For example, in a hypothetical force composition problem where flexibility in force composition is possible, it has been determined that the force must have a capability to destroy certain kinds of targets at certain expected ranges. Two possible alternatives are artillery and tactical air. The time required and the cost to destroy these targets by use of each alternative can be calculated. However, the importance of having a capability to attack these targets at any time of the day or night, regardless of weather conditions, is a matter of judgment. This

judgment can be better made when the cost-effectiveness of each alternative is known, in other words, the price to be paid for an all-weather capability stated in sufficient detail and accuracy to be useful for planning.

The effort to provide information so the commander can better exercise his judgment is also found in the estimate of the situation process. For example, a combat commander can better apply his judgment to selection among possible courses of actions when he has staff estimates--even if only rough--of the number of casualties he will suffer and the time required to accomplish the mission for each of the proposed courses of action. However, the variables that a staff estimate must contend with are relatively limited. The friendly organization is fixed, there is only one enemy in only one area and the options open to the enemy are relatively few. For example, the enemy can attack, defend, or execute some variation of a withdrawal. For practical purposes, neither the enemy nor the friendly force can introduce new weapons systems or change their fundamental organization or doctrines in the time period covered by the estimate of the situation.

The basis of cost-effectiveness analysis is that there are alternate ways of reaching an objective and each alternative requires certain resources and produces certain results. This is the same basis of the estimate of the situation which studies proposed courses of actions, each of which requires certain resources (forces and supplies) and produces certain expected results (time to take the objective, casualties incurred). A cost-effectiveness analysis is designed to examine systematically and relate costs, effectiveness, and risks of alternative ways of accomplishing an objective and designing additional alternatives (proposed courses of action) if those examined are found wanting. It is an analysis of the cost and effectiveness of a system, such as a forward area air defense system or an air mobile division, and all of the system implications. It can be considered as a kind of Consumers Research to assist in getting the most for the resources to be expended and not as a search for the cheapest regardless of effectiveness.

A major methodological difference between cost-effectiveness analyses and other military studies is the manner in which the results are presented. A staff study or a staff estimate, like a cost-effectiveness analysis, considers courses of action (alternatives). However, the staff estimate and staff study usually embody a single recommendation with the other alternatives either rarely mentioned or not as fully discussed as the recommended course of action. The commander (decision maker) is given the full reasoning behind the recommended course of action which is frequently presented so that the only option open is a "yes" or "no" decision.

In a cost-effectiveness analysis, the significant alternatives, the available facts, the reasoning process and the pertinent considerations pertaining to each significant alternative are presented. All identifiable assumptions and data are presented so that their validity can be questioned. In addition, and this is a major goal of a cost-effectiveness analysis, the dependence of the results of the analyses on these assumptions and data are tested.

The staff estimate and staff study do identify major assumptions. However, an implied assumption is often introduced when several different courses of action are open and a decision is made to proceed in one direction. Such a decision is then accepted as a known quantity when, in reality, it really is an assumption. There are many reasons for such assumptions, but frequently the result of the study or estimate is not tested for sensitivity to such hidden assumptions.

Cost-effectiveness analysis places great emphasis on use of numbers and calculations in any effort to determine quantitative factors where possible. Of course, there are many aspects of military activities that cannot be reduced to a quantitative factor. There is now no valid way of assigning a number to morale, the psychological effects of a certain military operation, or a host of other factors. However, it is possible to calculate the number of 155-mm howitzer rounds and total cost required to destroy a certain type of target. The impact of factors such as morale, training, reliability of allies cannot yet be calculated and are now matters of intuitive judgment. A cost-effectiveness analysis seeks to quantify what can be logically calculated so that the decision maker knows the extent to which intuitive judgment must be used in making a decision.

Essential Elements

The essential elements of a cost-effectiveness analysis are:

1. Objective(s) (functions to be accomplished).

2. Alternatives (feasible ways of achieving the desired military capability or accomplishing the function).

3. Cost of resources required by each alternative.

4. A set of mathematical or logical relationships among the objectives, alternatives, environment and resources (models).

5. A criterion for choosing the preferred alternative.

The Objective

The determination of the objective is often complex. In order to design alternatives properly, the problem must be analyzed to determine the real functional need underlying the requirements for certain organizations and hardware systems. Thorough examination of the functional need usually brings insight into the problem and leads to generating alternatives that may accomplish the desired goal. Close examination of objectives stated only in terms of specific organizations or systems often discloses that the net result is not a significantly new or improved capability but a relatively minor product improvement. This does not imply that product improvements are not needed but rather that a full understanding of the true significance of what is being proposed for purchase is necessary. For example, in stating a requirement for an artillery system with a specified minimum range capability, the real objective may be a capability to destroy certain kinds of targets under certain conditions. By examining the problem from the functional basis, the planner is better able to understand the problem. This insight may lead to other alternatives that should be studied. The examination may show that the proposed new artillery system is only one alternative to accomplishing the objective and that another alternative may be preferable.

There are practical limits on the definition of the objective. Every military activity is part of a larger activity and it is necessary to draw the line at some point. However, the objective should not be unduly restricted by confusion with performance characteristics such as speeds, weights, muzzle velocities, hit-kill probabilities, and so forth.

Alternatives

In military planning there is rarely only one exclusive way of achieving a given objective. Each way has its own price tag of time, men, facilities, materiel, and money. Assume, for example, that the planning problem--admittedly over-simplified--is to design a new type of division with certain capabilities. In satisfying these capabilities, the TOE designer has many alternatives. For the same capability, is it better to have more mobility (trucks, aircraft, and other vehicles) and less manpower, or perhaps more mortars and fewer riflemen? The alternatives are limited only by creative imagination and good military judgment. By exploring alternative ways of using resources it is often possible to discover ways of achieving an objective with fewer resources, or accomplishing more with the same resources. All feasible and significant capabilities to accomplish the objective should be considered, including the capabilities of the Navy, Air Force, and Marines. Prejudices, "party-line" and other forms of preconceived notions should be avoided in the design of alternatives.

Cost

Determining the cost of each alternative is based on incremental costs. These are the net costs of adopting the alternative. Such costs are determined after due allowances for those resources already paid for regardless of whether the alternative is adopted, and would be available for use under the alternative if it were adopted. In determining the cost of an alternative all the resource implications are considered. The alternative is treated in a system context. For example, the cost, admittedly oversimplified, of adopting a new radio would include not only the cost of the radio and its development, but also the costs of training people to operate it, the total cost of maintaining the radios, and the cost of the additional radios required for maintenance float, replacement, combat consumption, and so forth.

Costs need not be stated in precise terms down to the last dollar or man. However, the costs must be accurate enough to permit evaluating the military worth (effectiveness) together with the costs. Like everything else, this rule must be applied with discretion. In dealing with systems way out in the future the accuracy of the cost estimate, whether it is an absolute figure or a range, probably is inverse to the distance out in the future. Usually cost estimates are tested by sensitivity analysis. These are repetitive analyses using different quantitative values to determine if the results are sensitive to the values assigned. Such analyses give the decision maker a better understanding of how much uncertainty is involved if there are significant errors in the cost estimates. He can then better judge if the investment is worth the payoff considering the uncertainties involved.

Models

Models are used in cost-effectiveness analysis to cope with the host of variables that are inherent in problems of the future. A model is simply certain relationships expressed in some way to simulate real or expected conditions in order to foresee, even to a limited extent, the expected outcome of a course of action. Models assist in simplifying the problem, in identifying the significant components and interrelations, in determining which variables are especially important for the decision at issue, and which variables can be suppressed. In this manner, the decision process can be more precisely focussed on those areas which require a judgment decision.

Models range from simple graphs to complex equations and can also take the form of a wargame or field maneuver. The estimate of the situation and staff estimates also use models. The comparison of proposed courses of action against enemy capabilities or expected difficulties and the comparison among the proposed courses of action represent uses of models to foresee the future outcome of an action.

All models, simple or complex, are abstractions of the real world and their validity depends on the proper selection of assumptions and the correctness of the relations portrayed, and the pertinence of the factors included in the model. Two aspects of model building are particularly troublesome, quantification and the treatment of uncertainty. Some variables are difficult to quantify, such as the continued availability of certain support from an ally. This difficulty leads either to the neglect of such variables by ignoring them or by a qualitative modification of a solution derived from the treatment of other variables that have been properly quantified. Such treatment often results in the difficult-to-quantify variables being lost within all the other qualitative considerations that must be weighed when the time comes to recommend action on the basis of the solution from the model.

The influence of the variable that cannot be quantified and all uncertainties, must be specifically addressed in the model unless it can be demonstrated by logic or analysis that they are trivial, affect all alternatives roughly the same, or the results are insensitive to them. Guessing may lead to disaster. For example, if there is uncertainty about 8 factors, a best guess might be made on each of them. If there is a 60% probability that each best guess is right, then the probability that all guesses are right is less than 2%. Relying on best guesses, in this case, would be ignoring all the outcomes with more than 98% probability of occurring. Uncertainties and the problem of the factors that cannot be quantified can be handled through various techniques such as Monte Carlo sampling, contingency analysis, (see Glossary) and even wargaming for certain purposes.

Models that portray relations incorrectly also lead to false results. For example, some models are based on the persistence principle which states that what is happening or has happened will persist. This type of model is dangerous except for very short-term uses. For example, it is wrong to assume that the enemy tactics used during the Korean war will continue to be used in the future against new types of equipment and tactics that may be introduced. Some models depend on extrapolation which assumes that trends will continue uninterrupted. Such models lend themselves readily to mathematical treatment but are often erroneous because of failure to consider what is called the Law of Diminishing Returns. For example, a machine gun can fire at a certain high rate. However, this high rate cannot be maintained for very long (extrapolation) because the barrel would soon be burned out.

Models can be classified into two general types--exact (deterministic) or probabilistic. An exact model of warfare, of course, is impossible in peacetime. However, it is possible to create an almost exact model of some specific piece of hardware or activity and subject it to test. The final product of the model will then closely approximate the results from the actual hardware or activity. March graphs used for planning administrative movements are examples of deterministic models. Most military problems are, by nature, made up of uncertainties. Consequently, they are considered as probabilistic when the uncertainty is identified by a probability factor. For example, a wargame using a certain kill probability for an air defense system is a probabilistic model.

The construction of models to evaluate effectiveness is often difficult. The difficulties arise in selection of criteria of effectiveness. It is relatively easy to measure the comparative effectiveness of two similar pieces of equipment designed to accomplish the same general objective as, for example, in comparison of a towed 105-mm and a self-propelled 105-mm howitzer. However, it is more difficult to compare the effectiveness of general purpose force organizations such as two different kinds of divisions or even two equal-strength infantry battalions having the same general kinds of weapons but one having three rifle companies and the other having four. The impact on effectiveness of intangibles such as morale and leadership can hardly be calculated and requires the application of judgment. Each study virtually requires a consideration of its own criteria of effectiveness.

Models used in cost-effectiveness analysis sometimes tend to become mathematical and abstract. Consequently, they may be difficult to understand. A good cost-effectiveness analysis strikes a balance in the use of models between simplicity and retention of enough detail to ensure that the expected outcome of an expected action will be adequately portrayed. In any case all models have certain common elements. These

are broadly stated as a definition of the problem, principal factors or constraints, verification and the decision process--or application of criteria.. The validity of conceptual or mathematical models cannot be verified in a cost-effectiveness analysis by controlled experiments. At the best, they can be tested by their workability. Questions 37 to 44 in the next chapter are designed to assist a review to test the workability of models used in cost-effectiveness analyses.

Criteria

The most widely used criteria in Army studies for selecting the preferred alternative are usually based on either equal cost or equal effectiveness of the alternatives. Another method, known as incremental effectiveness at incremental cost, is used in special cases. In the equal cost form it is assumed that there is an arbitrary fixed budget or series of fixed budgets, and the analysis determines which alternative gives the greatest effectiveness for the same expenditures of resources. In the equal effectiveness form, a specified and measurable military effectiveness (capability) is stated and the analysis is to determine which alternative achieves this effectiveness at least cost. The incremental effectiveness at incremental cost method relates the increase in effectiveness achieved to the associated increase in resources involved. This method is normally used only as a last resort when neither costs nor effectiveness of alternatives can be made equal, e.g., when a capability based on a new technology is to be added to the force and this new capability cannot be approximated by any practicable combination of existing materiel and men.

Role of Judgment

Judgment is used throughout a cost-effectiveness analysis in the same manner as in the making of an estimate of the situation or a staff estimate. Judgment is used in analyzing the objective, deciding which alternatives (courses of action) to consider, which factors are relevant and the interrelations among these factors, which numerical values are to be used, and in analyzing and interpreting the results of the analysis. The goal of a cost-effectiveness analysis is to keep all judgments in plain view and to make clear the logic used. It also shows the sensitivity of the results to the significant judgments made. The depth of a cost-effectiveness analysis is tempered by the time and manpower available and the importance of the subject matter. A cost-effectiveness analysis requires resources and it must serve as an aid to the making of decisions and not be a mere intellectual exercise.

Review of Studies

There are probably almost as many different ways of reviewing a study containing cost-effectiveness analysis as there are reviewers. Furthermore, the time available for review is variable and studies lack a common format. It is suggested that the points listed below be checked specifically in the early stages of a review.

a. Statement of criteria used to judge effectiveness.

b. Statement of criterion used to select preferred alternative.

c. Use of incremental costs.

d. Explanation of logic of models.

e. Presence or lack of analysis of sensitivity of the results to significant data and assumptions.

Without these elements being present, the study will probably be of poor quality.

Army—conducted studies containing cost-effectiveness analysis usually do not have a uniform organizational pattern but many generally follow the Staff Study format. On that basis, the key questions in the next chapter have been grouped under these headings:

Statement of the Problem
Assumptions
Alternatives
Documentation
Cost
Relationships (Models)
Effectiveness
Criteria
Conclusions and Recommendations

The grouping under the above headings inevitably leads to some duplication of material, particularly on the use of analytical tools such as sensitivity and contingency analysis. This duplication has been kept to a minimum but full coverage has been retained under each heading as a convenience to the reviewer who wishes to refer to a specific heading.

The Glossary is designed to give a non-technical definition of terms frequently used in cost-effectiveness analyses.

The annotated Bibliography has been designed for the reviewer who desires to read further into the methodology of cost-effectiveness analysis.

Chapter II

KEY QUESTIONS*

STATEMENT OF THE PROBLEM

1. IS THE PROBLEM STATED THE REAL PROBLEM?

An improper statement of the problem often results in either studying the wrong problem or precluding consideration of worthy alternatives. These defects are usually avoided by a statement of the problem in terms of a functional need--the job(s) to be done--without implying how it is to be done. A statement of the problem in terms of requirements for kinds of forces, systems, or performance characteristics, except if it is a follow-on to a previously approved study of a functional need, should be critically examined to ensure that the wrong problem is not being studied and that worthy alternatives are not automatically excluded from consideration. For example, although the stated problem (no previous study of functional need) may be to select a rifle to meet certain capabilities (requirement statement), the real problem might be providing the rifle squad with adequate firepower to accomplish certain functions (functional need). In such a case, a rifle is only one possible alternative.

A word of caution is in order. There often is a practical limit on the depth of the statement of the functional need or the study may become unmanageable. For example, in the case cited the functional need could be conceivably so stated that the rifle squad itself becomes only one alternative to solving a larger problem. To avoid this difficulty, either certain broader decisions must be considered as made, thereby narrowing the scope of the study, or the broader study undertaken. When the former approach is taken, the study is known as a suboptimization. The reviewer, based on his knowledge and judgment, must determine if the suboptimization has so narrowed the scope of the problem that the real problem has been missed or worthwhile alternatives excluded.

2. DOES THE STUDY IDENTIFY IMPLIED SIGNIFICANT COMPONENTS OF THE PROBLEM THAT MUST BE FULLY TREATED IN THE STUDY?

Like the mission statement in an estimate of the situation, the problem to be treated in a cost-effectiveness analysis must be analyzed to identify all functions that must be performed. Some of these implied

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*Those questions that are considered particularly important and of widest application have been underlined.

functions are often not apparent at first. The reviewer should watch for implied significant component parts of the problem that are neither identified nor treated fully in the study. The reviewer should also watch for other problems that are opened up or revealed by the study that should be further investigated.

ASSUMPTIONS

3. ARE ALL ASSUMPTIONS IDENTIFIED?

The reviewer should watch for assumptions that are not identified as such because assumptions imply a limitation or a judgment. In order to evaluate the study properly, it is necessary to assess the impact of the limitations and the validity of the judgments contained in all the assumptions. An example of a common assumption that is often not identified is that a given unit operates by itself. As a result, in measuring the effectiveness of a division, for example, inadequate consideration is sometimes given to the support the division receives from non-divisional units such as corps artillery or tactical air units. This failure to consider non-divisional support may lead to erroneous conclusions and recommendations. Another frequently hidden assumption is that the enemy's doctrine and tactics are rigid although ours are flexible.

4. ARE THE ASSUMPTIONS UNDULY RESTRICTIVE?

Assumptions are properly used to narrow the scope of the study to manageable proportions. However, the assumptions should be examined to determine whether they unduly restrict the study by eliminating possible significant alternatives or by narrowing the scope of consideration to the point that the conclusions and recommendations may be in error. This examination may be required throughout the review of the study and not only during the review of the stated assumptions.

Assumptions covering the subjects listed below often unduly restrict the scope of the study and lead to questionable conclusions and recommendations.

a. Non-availability or limited availability of support from other services (e.g., tactical air support or MATS effort).

b. Locale of operations.

c. Duration and intensity of operations.

d. Enemy organization, operations, and reactions to our decisions.

e. Time period covered.

5. DO ANY OF THE MAJOR ASSUMPTIONS UNJUSTIFIABLY TREAT QUANTITATIVE UNCERTAINTIES AS FACTS?

An uncertainty can be defined as the lack of definitive knowledge for assigning values or probabilities to factors that influence decisions. Uncertainties can be either quantitative (risks) or qualitative. (See **UNCERTAINTY** and **RISK** in Glossary.) Examples of quantitative uncertainties are hit-kill probabilities, equipment availability rates, ammunition expenditure rates, and reliability statements. The availability of base rights in a foreign country at some future time, or the start of aggression by the potential enemy in a given year are examples of a qualitative uncertainty. (See next question.)

The reviewer should be alert for stated and implied major assumptions that assign fixed values to quantitative uncertainties and then treat these estimates as facts. A common example is the assumption that a proposed weapon system will have a certain hit-kill probability. It is often better to handle significant uncertainties by sensitivity analysis. This is a repetitive analysis using different quantitative values to determine if the results are sensitive to the values assigned. When significant uncertainties are treated as facts by assumption, the conclusions and recommendations of the study may be no more valid than the assumption unless it can be demonstrated that the conclusions and recommendations are not sensitive to plausible errors in the "facts."

The number of sensitivity analyses required, and feasible, is a matter of judgment. There are limits to the time and manpower available for a given study. Sometimes an educated guess, considering all the circumstances, will suffice. In effect, the reviewer must judge whether the study agency has performed adequate sensitivity analyses considering all the circumstances, the importance of the subject, and whether further sensitivity analysis may significantly affect the conclusions and recommendations.

6. DO ANY OF THE MAJOR ASSUMPTIONS TREAT QUALITATIVE UNCERTAINTIES AS FACTS?

Major qualitative uncertainties treated as assumptions also tend to dictate conclusions. A common qualitative uncertainty that may dictate the conclusions concerns the estimate of the enemy. Many studies are based on intelligence estimates, or target arrays prepared or approved by the Defense Intelligence Agency. However, these estimates are sometimes assumed to be facts. In such cases, this often results in the enemy being considered to be inflexible and no allowances are made for him to react in different ways to our operations or to our introduction of new capabilities. When it is not definitely known how we will operate

or be equipped 10 years hence, it is questionable to assume that the enemy operations and equipment in the future can be predicted with certainty.

Other qualitative uncertainties, stated or implied, that should be treated with caution are those associated with political considerations. Examples are availability of base rights, assurance of overflight permission, and composition of political and military alliances on either side.

Treatment of the kinds of uncertainties discussed above in an analysis is not simple, but the effects of such uncertainties on the conclusions should not be neglected in a study. One method to cope with significant uncertainties of this kind is to use contingency analysis. This involves repetitive analysis with different qualitative assumptions, such as type of conflict or enemy capabilities, to determine their effects for comparison with the results of the initial analysis. The amount of contingency analysis required has to be a matter of judgment, as discussed in the previous question.

7. ARE THE MAJOR ASSUMPTIONS REASONABLE?

Major assumptions should also be tested to determine if they are reasonable. This test can be facilitated if the study documents or provides some explanation of why each assumption was made so that the reasons can be evaluated by the reviewer. A useful technique for reviewers is to try to think of other major assumptions that are plausible. If these invalidate the conclusions and recommendations, then the study is questionable.

ALTERNATIVES

8. ARE CURRENT CAPABILITIES ADEQUATELY CONSIDERED AMONG THE ALTERNATIVES?

Current capabilities should not be omitted from consideration in construction of alternatives except for valid reasons that are clearly stated. Valid reasons may include failure of the current system to accomplish the current mission, or a significant degradation of capability relative to that of the potential enemy. Consideration of current capabilities sometimes helps show whether the proposed new system or organization is an improvement that is worth the expenditure of new resources. By considering current capabilities, much of whose costs are already paid for, as an alternative, the study can show the difference in effectiveness and costs that result from the adoption of the proposed new system or organization. (See question 23.) Current capabilities should also be considered, where appropriate, as a component of an alternative.

9. ARE "TRADE-OFFS" WITH EXISTING SYSTEMS OR ORGANIZATIONS ADEQUATELY CONSIDERED WITHIN THE ALTERNATIVES?

Where appropriate, the design of alternatives should consider "trade-offs" with existing systems or organizations. Possible examples are: (1) in studying the increased use of Army transport aircraft an alternative might include reduction in other means of transport; (2) in a study on an improved fire control system an alternative might include a reduction in ammunition stockage.

10. ARE THE APPROPRIATE CAPABILITIES OF THE AIR FORCE, NAVY, OR MARINE CORPS CONSIDERED AMONG THE ALTERNATIVES?

The alternatives should consider the capabilities of Air Force, Navy, or Marine Corps as appropriate. The Army usually conducts combat operations with the support of one or more of the other Services and the other Services are charged by law with furnishing certain support to the Army. These types of supports are listed in JCS Publication 2 (UNAAF). For example, CONUS air defense is not the exclusive responsibility of either the Air Force or the Army. A CONUS air defense problem must consider Army surface-to-air missiles, Air Force manned interceptors, and Air Force surface-to-air missiles.

Current and projected capabilities of the other Services can be obtained from a number of different sources including the Five-Year Force Structure and Financial Plan maintained by each Service. The reviewer should bear in mind that functions such as air defense, the

attack of surface targets, reconnaissance in the vicinity of the FEBA, and transportation within a theater are not the exclusive responsibilities of the Army.

11. ARE MIXTURES OF SYSTEMS (ORGANIZATIONS) CONSIDERED AMONG THE ALTERNATIVES?

The reviewer should watch for failure to consider appropriate alternatives that are based on mixtures of two or more systems (organizations) to combine the best features of each. For example, in comparing certain transportation systems one alternative for surface transportation might be a combination of truck, rail and water systems rather than only a truck system. In the same manner, the study of a proposed new missile system might consider as an alternative a suitable combination of existing missile and gun systems and aerial fire support rather than only an existing missile system.

12. ARE ANY FEASIBLE AND SIGNIFICANT ALTERNATIVES OMITTED?

A major contribution that a reviewer can make is to point out significant and feasible alternatives that the study may have failed to consider. If any of the answers to the previous questions on "Alternatives" are in the negative then it is possible that some feasible and significant alternatives were not considered. However, the reviewer must exercise judgment before criticizing a study for failure to consider all possible alternatives. There are practical limits on the time and manpower available for a given study. The relative importance of the decision on the subject under study will also influence the number of alternatives examined. The reviewer should consider these aspects in determining whether feasible and significant alternatives have been omitted to the detriment of arriving at sound recommendations.

On the other hand, a large number of alternatives may only indicate that minor variations have been considered as new alternatives. Excessive use of such minor variations as alternatives often beclouds significant choices.

DOCUMENTATION AND DATA

13. IS THE STUDY ADEQUATELY DOCUMENTED?

A key element of systematic analysis is sufficient documentation of methods and sources so that with the same material, other study groups can arrive at substantially the same results. Without such documentation, a study appeals for acceptance solely on faith in the authority and expertise of the study group and without critical examination of the sources and methods used to arrive at the recommendations.

The test of adequacy can be applied by examining the models, data, assumptions, etc., to determine if they are stated in such a way that another study agency could trace through the steps of the study and arrive at substantially the same results and conclusions. A study that is not adequately documented will usually fare poorly when reviewed by agencies lacking the detailed knowledge of the problem that can sometimes compensate for poor documentation. Inadequately documented studies may require only slight additions to be properly documented.

14. ARE THE FACTS STATED CORRECT?

It is usually neither possible nor necessary for a reviewer to verify all the factual material presented in a study, but it is advisable to spot check. Particular attention should be paid, where possible, to the factual material on which conclusions and recommendations depend. If many errors are involved then a thorough verification of the facts presented may be in order.

In reviewing factual material, its source should be examined critically. For example, frequent use is made of data contained in FM 101-10, "Organization, Technical, and Logistical Data" and similar publications. The data contained in these manuals are usually averages of historical data obtained from certain kinds of operations in specific theaters. The unquestioning use of these average figures may lead to erroneous conclusions because the use of an average hides significant variations that exist in the real world. A tank battalion does not always cover the same number of miles each day even over the same terrain. Further, the data contained in the reference manuals may not have been computed for the purpose required in the study and considerations important to the study may not be included in the calculations. For example, ammunition expenditure rates contained in FM 101-10 are based on World War II and Korean experience and organizations. The use of these rates for projected operations in the 1965-70 time frame would be questionable.

Projection of current operational experiences into future time frames should also be examined critically. For example, a study used as data that an armed helicopter's missions are A% escort, B% casualty production, and the remaining missions for suppressive fire. These data were obtained from experience in Viet Nam operations. This unquestioning projection of such data into future operations in other areas fails to allow for possible introduction of significantly new US and enemy tactics and may result in conclusions and recommendations on how better to cope with the last war.

15. ARE THE FACTS STATED WITH PROPER QUALIFICATION?

In addition to checking the validity of the factual material, it is good practice to check the factual material for completeness. Some material may be factually correct in isolation but may take on a different significance when other facts are added. For example, it is true that infantry units can march at an average rate of 2.5 miles per hour. However, this rate is valid only on relatively level roads.

16. ARE FINDINGS AND DATA FROM FIELD EXERCISES AND FIELD TESTS USED?

Field exercises and field tests can be excellent sources for effectiveness data. When used in a study, such data should be carefully examined. The reviewer should determine whether the data were obtained by measurements or by judgment of individuals and if similar data would likely be obtained if the field test or field exercise were conducted again by another agency or unit. The circumstances surrounding the field exercise or field test should be reviewed, where possible, to determine if any artificialities (there are always some in any peacetime operation) were of sufficient influence to affect the results of the study based on field data. Field exercises usually have many parameters and very few runs, therefore making it very difficult to single out cause and effect.

Common artificialities that may significantly affect data from field exercises and field tests include:

a. Inability to assess effectiveness of air defense fires, air-to-surface fires, and ground-to-ground fires.

b. Lack of realistic levels of support from the other Services or other supporting units. Often this support is either not available or available in abnormally large amounts.

c. Use of administrative breaks for rests, intensive resupply, and maintenance operations.

d. Unrealistic maneuver and deployment because of restricted maneuver areas.

e. The units or quantities of materiel tested are not a valid sample either because of inadequate size or of bias in composition.

f. Poor or inadequate reporting of events of the exercise.

g. Effect on actions of participants caused by use of only blank ammunition.

17. ARE THE DATA FROM SUPPORTING WARGAMES VALID?

Studies sometimes use the findings of wargames as facts. In evaluating such facts, the reviewer should bear in mind the nature of wargames. Basically, a wargame involves a hypothetical situation in which two opposing sides interact in accordance with a set of more or less definite rules. In all forms of wargames, the play is determined either by mechanistic rules or judgments made by individuals or both. These rules and judgments are based on assumed situations and known or assumed facts and system characteristics. Well planned and executed wargames are excellent teaching devices and provide the participants with good insights into the problem gamed. Such games, if well documented, usually provide a body of synthetic data which, when analyzed, provides clues to problem areas that need further investigation.

In determining the validity of the findings of wargames, the reviewer should judge how well the game portrayed reality and should satisfy himself on the validity of the judgments and assumptions used in the conduct of the game. The study should lay out for scrutiny the major judgments and assumptions used in the wargame. It is recognized that it is usually not possible to lay out all judgments and assumptions used in the wargame. In any case, the reviewer should weigh the dependence of the conclusions and recommendations on the findings of the wargame and consider whether other competent players playing the same game would have arrived at similar results.

18. ARE THE PERFORMANCE CHARACTERISTICS VALID?

Performance characteristics data are often the key elements in the determination of the effectiveness of a system. In evaluating

the validity of performance characteristics, the source of the data should be examined. When the claimed performance characteristics are essential to the conclusions and recommendations and the source of the data is not clearly stated, additional information may be required from the agency that prepared the study. This may not be necessary if the study contains a sensitivity analysis of a reasonable range of values for the performance characteristics.

Performance characteristics based on a manufacturer's claims are often too optimistic. Performance characteristics derived from tests at research installations also require examination. Sometimes, such performance characteristics are derived under controlled conditions that neglect the man-machine relation that exists under field condition. Even performance characteristics derived from field tests should be examined. Such tests can, at times, produce misleading results due to artificialities caused by various peacetime restrictions such as safety regulations and choice of test areas.

If faced with questionable performance characteristics that are key to the conclusions, the reviewer should consider: (1) performing a sensitivity analysis himself if his time and the data in the study permit; (2) requesting validation of the performance characteristics and sensitivity analysis.

19. ARE ANY OF THE DATA DERIVED FROM QUESTIONNAIRES?

The data obtained from questionnaires should be examined to determine the validity of the questions, the adequacy of the sample and statistical procedures, and the expertness of the personnel questioned. For example, one study cited data on the frequency of kinds of missions expected to be flown by Army aircraft in a conventional war. The data were based on a questionnaire completed by Army aviators at one Army post. There was no operational experience applicable to the study and an educated guess or subjective judgment was in order. However, in this case, the judgment of those who order Army aviation missions flown (commanders, operations and intelligence officers) should have been elicited rather than the judgment only of those who execute the missions.

20. ARE GUESSES AND INTUITIVE JUDGMENTS IDENTIFIED?

At times it is necessary to fill in data gaps with educated guesses and intuitive judgment. These educated guesses and judgments should be identified in the study and not "swept under the rug." The reviewer should evaluate these judgments and weigh their impact on the conclusions and recommendations.

21. IS THE COST MODEL IDENTIFIED?

Every cost-effectiveness analysis contains a cost model. A cost model generates cost estimates by application of cost estimating relations and cost factors to specified physical resources. (For a further discussion on models in general see question 37.) This model can be very complex and computer assisted or it may consist of a few relatively simple equations readily computed by hand. The study should sufficiently identify the cost model so that the reviewer can determine how the total system cost estimates were derived from the material in the study. If the material in the study does not permit the reviewer to do this, then additional information is required from the agency that prepared the study.

The cost models are utilized to estimate the probable economic impact on the Service (or Nation) of introducing a new capability. For planning, these costs are normally stated in terms of research and development costs, investment costs, and operating costs. Research and development costs include those costs primarily associated with the development of a new capability to the point where it is ready for operational use. Investment costs are those costs beyond the development phase to introduce a new capability into operational use. Operating costs are recurring costs required to operate and maintain the capability.

22. ARE THE COST ESTIMATES RELEVANT?

Cost estimates depend on the problem under study and can rarely be obtained from books containing cost data although cost factors and cost estimating relations (CERs) can sometimes be found in such books. For example, a hypothetical study considers as an alternative a new kind of light infantry division which has been designed to the extent of an outline TOE. The answer to the seemingly simple question, "What is the cost of this new division?" depends on many factors including:

> Will it be an additional division to those already in the force structure?
>
> Will it replace an existing division? If so, what kind?
>
> Where will it be stationed? e.g., in the CONUS, Pacific, Europe, etc.

Will it have new Standard A equipment, or will existing assets of Standard B type equipment be used?

Are there any existing Army units whose personnel, equipment, and facilities can be used by the new division?

The determination of which costs are relevant requires considerable analysis and judgment. It is not possible to prepare a universal list of costs that are always relevant. Ideally, a study should indicate why certain costs were considered relevant and others not. The questions that follow are designed to help the reviewer determine whether the cost estimates used in a study are relevant.

23. ARE INCREMENTAL COSTS CONSIDERED?

Inherited assets are those resources such as installations, equipment, and trained personnel inherited from earlier systems which are phasing out of the force structure and are usable in one or more of the alternatives under study. The costs which are usually pertinent for planning purposes are those costs yet to be incurred. For example, a study considers as an alternative the conversion of certain artillery units from tube to missile weapons. In determining the incremental costs consideration should be given to the inherited assets of trained personnel, equipment, and facilities that are or can readily be made common to both units.

Sunk costs are those costs already expended. These previously incurred costs are normally excluded from costs presented in cost-effectiveness analysis. For example, a study considers as possible alternatives weapons systems A, B, and C, each with an associated research and development cost. Only alternative A is already under development. The cost already expended on Alternative A is a sunk cost and the research and development cost of Alternative A in the study should be only what must yet be spent, (to complete the research and development of Alternative A).

An occasional error is the failure to consider the research, development and investment costs of existing systems as sunk costs. For example, in a hypothetical study of the conversion of certain artillery units from tube to missile weapons, one of the alternatives is retention of all of the tube weapons units. The cost of that alternative would not include the sunk costs represented by the research and development and investment costs already expended in bringing those units into the force structure.

Including the costs of inherited assets and other sunk costs leads to distorted cost estimates with consequent effect on the conclusions and recommendations.

24. ARE DIRECTLY RELATED SUPPORT COSTS INCLUDED?

Cost estimates of systems or organizations should include the proportionate cost of those other units or elements required in direct support. For example, the cost estimate of HAWK battalions should include the costs of the associated HAWK direct and general support detachments. In the same manner, the cost of aviation units should include a direct share of the cost of aviation maintenance units. Failure to include directly related support costs may result in misleading cost estimates of alternatives.

25. ARE COMBAT CONSUMPTION, REPLACEMENT/CONSUMPTION, AND MAINTENANCE FLOAT COSTS INCLUDED?

Cost estimates for the major equipment items should include not only the operational equipment assigned to organizations, but also the costs for those additional items required for initial stockage as well as replacement items over the period in which the system is to be in use. (See question 32.) If the resource implications for procuring and maintaining authorized maintenance float, replacement/consumption, and combat consumption stockage are excluded, the total costs of the system alternatives may be significantly misleading. (These levels of stockage are, of course, subject to logistics guidance.) For example, a common error is to include only the cost of the basic load of ammunition and to neglect the cost of the additional ammunition requirements for support of the weapon system or organization. The total ammunition required, to include peacetime training requirements and expenditures in the first part of a war until wartime production becomes available, must be purchased and stocked in peacetime.

26. ARE ALL TRAINING COSTS INCLUDED?

The resource implications of training military personnel can be significant. Initial training costs represent the resources required for the training of personnel necessary for introduction of the alternative into the force structure. The availability of fully-trained personnel, as well as the number of personnel requiring complete or transitional training, are taken into consideration in determining the resources required. Annual training costs represent the resource implications for training replacements. These replacements are required because of normal attrition.

Training costs usually include such items as: (1) procurement of equipment utilized for training purposes; (2) construction of any necessary additional facilities; (3) operation and maintenance costs of the facilities; (4) the pay and allowances of the trainees. For example, the cost implications of communications-electronic equipment utilized for training purposes could be highly significant.

27. ARE CONSTRUCTION COSTS INCLUDED?

The costs for additional installations or facilities are often overlooked yet these costs can be important. If the study does not include any construction costs and does not state how the facilities were obtained, then the reviewer must either satisfy himself that no construction is required or take necessary steps to have the study corrected.

28. ARE THE COST DATA REASONABLY ACCURATE?

Although it is not usually possible for a reviewer to check all cost data for accuracy, he should spot-check and examine the sources of the data.

Cost data furnished by manufacturers should be viewed critically. Experience has shown that such data are usually understated, particularly for advanced systems. Advanced system costs stated as an exact figure rather than as estimated lower and upper values are particularly suspect.

The basis of the cost data for advanced systems should be included in the study. There are a number of ways for arriving at such estimates. One commonly accepted method relates the cost data for the components of existing analogous systems to the cost of the advanced system. Unsupported cost data are suspect.

Great accuracy in cost estimates is not required and often is not feasible. In fact, in dealing with costs of advanced systems it is usually more realistic to have a range of possible costs (upper and lower values) rather than the pseudo-accuracy of one cost figure which assumes no uncertainties in arriving at that figure.

29. ARE COST ASPECTS OF ALL ALTERNATIVES TREATED IN A COMPARABLE MANNER?

Inconsistency in handling the cost aspects of competing alternatives prevents an objective evaluation of their comparative or relative costs and usually leads to erroneous conclusions. It is not always possible to use the same cost estimating technique for calculating a cost element

such as attrition replacements. This is often the case in studies involving alternative systems of other military services. For example, one service may calculate aircraft attrition replacement as a function of an activity rate (e.g., per 100,000 flying hours) while another service may calculate it as a function of the activity inventory (3 percent of the active inventory per year). The reviewer should determine that the final dollar estimate is related to the actual resource requirements for the alternative and that computational peculiarities do not distort the cost results.

Treating alternatives in a comparable manner must not be carried to the point that costs which may be insignificant in one alternative are therefore not considered at all in other alternatives. For example, civilian personnel might not be used in one alternative but may be required by another alternative in significant numbers. To exclude this cost could distort the results.

30. ARE THE COST ESTIMATING RELATIONS VALID?

Cost estimating relations may be crude factors, simple extrapolation of recent experience, or complex equations with many variables. In all cases, the purpose of a cost estimating relation is to translate a specification of a physical resource into a cost. The design of valid cost estimating relations is a complex subject beyond the scope of this publication. However, several common errors made in establishing cost relations are discussed below.

Cost estimating relations should be based on current data or distorted estimates may result. For example, the maintenance cost per flying hour for an Army helicopter has decreased significantly over the past several years as new helicopters have been introduced into the force structure. If the cost estimating relations used in a study were based on information for early Army helicopters (e.g., 1946 through 1954 data) the maintenance cost per flying hour for a present system as well as for future systems alternatives could be distorted.

At times a properly constructed cost estimating relation may be inapplicable. If the system alternatives are very advanced developments, the cost estimating relations based on the current technology may lead to false results. For example, the V/STOL aircraft concept represents a departure from aircraft currently in production. While many design characteristics may be similar to present aircraft, there may be a number of factors which could increase the complexity and hence, the cost of the aircraft; a cost estimating relation based on the present state-of-the-art may not be appropriate.

31. IS AN AMORTIZED COST USED?

Amortized costs reduce the total program cost of the system to an annual cost by taking the total operating cost of the program, adding to it the research and development and investment costs, and reducing the total to an annual basis by dividing by the number of years of expected service life of the system. The same general procedure may be utilized to amortize the costs per month, per day, per sortie, etc. This approach disguises the differences between annual operating costs resulting from shifting deployment patterns over the life of the system and from a varying set of inherited assets over time. This approach makes an arbitrary allocation of the fixed costs of a system over time. There is no basis for the assumption that the last year of system life must be charged with the same amount of R&D cost as the first year. The first year gets the newest technology; the last year, obsolete technology. Further, an amortized cost does not present a true picture of the total resource implications. If the system is to be in the force structure for say 10 years the amortized annual costs may look relatively small, yet in reality there may be relatively large dollar costs. It is the total cost of the alternatives which is of primary concern.

The reviewer should attempt to convert amortized costs into total program costs and use such costs for comparative purposes. If this cannot be done readily from the material contained in the study, then additional information is required from the study agency.

32. WERE PEACETIME OR WARTIME COSTS INCLUDED?

The results of a cost-effectiveness study may be very sensitive to the use made of peacetime and wartime costs. The use of peacetime costs only may indicate that System A is preferred while the same study, if wartime costs were used, may have concluded that System B is preferable.

Peacetime costs may be defined as the costs associated with developing, buying, and maintaining a capability for potential war during peacetime. Such costs also include combat consumption stocks (war reserves) to cover the period from the beginning of a war until wartime production is able to replace battle losses. Wartime costs are the costs of procurement after the war has begun, as is the cost of replacing the combat consumption stocks if the war terminated during the useful life of the system.

In the case of general purpose forces there may be significant production of weapons and expenditure of resources after a limited conflict begins (as in the Korean Conflict and the military assistance rendered to South Vietnam). In this case, wartime costs could be significant.

However, wartime costs are difficult to determine because of uncertainty regarding the duration of the war, loss rates, and missions undertaken.

The reviewer should be guided in considering the proper cost approach (peacetime or wartime) by existing policy or directive from the agency directing that the study be made.

33. WAS A WARTIME ORDNANCE COST PER MISSION USED?

The use of a wartime ordnance cost per mission should be reviewed carefully. Variations on this approach include ordnance cost per target killed, per casualty and per sortie. This approach is usually deficient because of failure to consider all the costs of putting into place and maintaining a capability for potential war throughout the projected life of the system in the active force structure. Often, this approach includes only the ammunition costs expended during a brief battle, and neglects the bulk of the significant costs associated with developing, buying and operating the system in peacetime.

34. WAS AN AMORTIZED WARTIME-PEACETIME COST USED?

In this approach the total peacetime cost of the system is reduced to an annual basis as explained in question 31. To this amortized peacetime cost is added the estimated annual wartime replacement/consumption costs. No distinction is made between wartime and peacetime costs. This approach is deficient because: (1) it assumes the war will continue over the entire projected service life of the system; (2) the cost results use weighted wartime costs; (3) wartime and peacetime costs may not be commensurable; and (4) it does not present a true picture of the total resource implications as discussed in question 31.

Adding amortized costs in one stream to another annual cost stream infers that both cost streams represent the same total time duration. If this is not the case, then the two cost streams should not be added together because they are incommensurables. Adding the amortized peacetime costs to the annual wartime cost implicitly assumes that the war will continue over the entire "service life" of the system. If the peacetime costs had been amortized to a per day or per mission cost instead of a per year basis, the same result would hold; the inference being that the war would continue over the entire "service life" of the system. The implied assumption that the war would last for the "service life" of the weapon system is questionable.

Costs computed by this method are weighted because wartime costs do not cover the same length of time as peacetime costs. Such weighted

results favor the shorter time period--the wartime costs. It is only when the two cost streams are of equal length that the costs results are not distorted.

To assume that wartime and peacetime costs are commensurable may be erroneous. This assumes a common measure between the values of resources procured in wartime and those procured in peacetime. During wartime, the cost of a resource may be quite different from that in peacetime. Military budget constraints during peacetime and physical resource constraints during wartime may produce entirely different sets of costs for the same military resources. As a greater proportion of the national budget is shifted to military purposes during wartime, the scarcity of dollars for military resources may become relatively less or more than during peacetime. Commensurability between wartime and peacetime costs will depend upon such uncertainties as the type and duration of war and whether a war will actually occur.

35. WAS A DOLLAR COST ASSIGNED TO THE LOSS OF HUMAN LIFE?

Frequently, a study will assign a dollar cost to a human casualty. The loss of human life is certainly important in selection among alternatives. However, the value of a human life is incommensurable with the dollar costs associated with an alternative. It is better to treat human losses as a separate measure without assigning dollar values. Manpower availability in both peace and war is very important but this problem cannot be properly treated only in terms of dollar costs. Men and dollars may not be interchanged.

36. IS THE SENSITIVITY OF COST ASSUMPTIONS EXAMINED?

In comparing costs of alternative systems, it is important to determine whether the results are independent of the cost assumptions. For example, would ten years of peacetime operations as opposed to five make a significant difference in the relative costs of the alternatives? Would it make any difference if the procurement levels or number of units to be organized changed? The study should make clear the sensitivity of the cost estimates to the major cost assumptions. If the study fails to do this, the reviewer should attempt to determine if there is any such significant sensitivity by rough calculation.

37. ARE THE MODELS ADEQUATELY IDENTIFIED AND EXPLAINED?

The conclusions and recommendations of a cost-effectiveness analysis cannot be evaluated properly unless the models are adequately identified and explained. Every model portrays the real or expected world by abstraction and simplification in order to predict the outcome of a possible action (see Glossary). Therefore, the explanation of the model should be sufficient to provide ready understanding of which aspects of the real world are included in the model, which aspects have been omitted, and the underlying assumptions for the abstraction. Basically, a good model emphasizes the specific areas in which decisions are to be made by removing those relatively constant elements of the real or expected world that can be described with a great degree of certainty.

The study should contain sufficient explanation to permit tracing the operation of the model from input to output. The detail should be sufficient to permit calculation of new results from different input values (sensitivity analysis). In cases where a model is machine-programmed, sufficient explanation should be provided for following the general logic of the program.

38. ARE COST AND EFFECTIVENESS LINKED LOGICALLY?

A properly structured cost-effectiveness analysis contains a number of models that link effectiveness and cost through logical interrelations. Usually there are some kinds of an effectiveness model, a system and organization model, a cost model, and a cost-effectiveness model. The exact nature and number of these models will vary with the problem. The study should provide sufficient information and explanation for the reviewer to follow the logic by which the models relate cost and effectiveness.

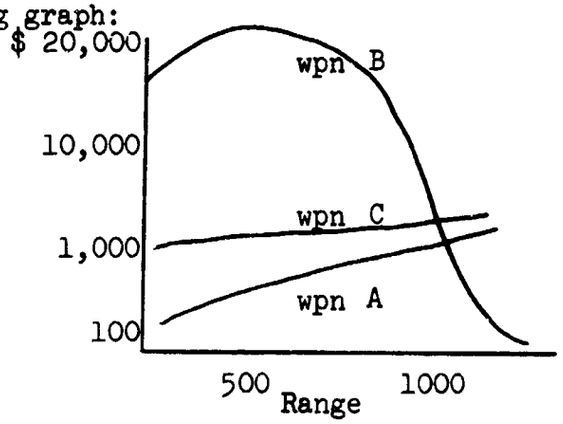
An effectiveness model relates measures of effectiveness to measures of performance in an operational context. For example, a study on combat vehicle weapons systems used as a measure of effectiveness the probability of 1, 2, 3, ... friendly tanks winning an engagement with 1, 2, 3, ... enemy tanks under different tactical situations. This was related to performance measures such as muzzle velocity, warhead specifics, turret slewrates, turret stability, hull characteristics, rate of fire, target acquisition accuracy, and others, under various tactical situations and rules for conduct of fire.

A system and organization model describes the physical resources required to provide the performance used in the effectiveness model.

For example, in the combat vehicle weapons system study referred to, this included the physical description of each alternative; the complete vehicle, ammunition, armament, fire control, communications, TOE unit description, the support and maintenance requirements, and so forth, consistent with the planned operational concept.

A cost model relates dollar costs to the physical resources (and their peacetime activity rates) described in the system/organization model. The cost model applies cost estimating relations and factors. For example, the same study used the total future cost of acquisition and ownership (R&D, initial investment, annual operating) for various quantities of systems. Included in these total costs were not only the development and procurement of the preferred item but also such additional costs caused by training of personnel, peacetime ammunition use, equipment maintenance, etc. (See question 22.)

The cost-effectiveness model finally relates the costs of each alternative to its effectiveness under varying assumptions. Depending on the criterion, the model may compare effectiveness and costs of alternatives at equal cost, at equal effectiveness, or at different cost and different effectiveness. (See page 10.) The method and the techniques used to achieve this cost and effectiveness relation should be logical and explained. For example, in one anti-tank weapons study the equal effectiveness method (winning the duel - all pertinent factors considered) was employed. Effectiveness was related to cost by a numerical formula for calculation of cost of achieving duel success at a given range under specified conditions. This permitted plotting the following graph:



The graph shows the cost of winning a "duel," i.e., killing the target at various ranges. (The graph portrayed above is highly simplified. In the actual study rather than a simple line, a band was used to portray the variance in costs for winning a duel at a given range. See Bibliography Item No. 1, pages 13-17 for a more complete description.)

39. DOES THE MODEL TREAT THE PROBLEM IN A SYSTEM CONTEXT?

Most military systems have many subsystems, sub-subsystems and so forth. Models should provide for the proper relations among subsystems so that the full implications of a change in one part of the system will be reflected in the rest of the system. For example, a model in a study of an airborne surveillance system must not only show the interrelations among the aircraft (or drones), the sensors and their maintenance, but also the interrelations with the information processing functions to be performed on the ground.

40. DOES THE MODEL ALLOW FOR ENEMY REACTION?

It normally takes several years to implement fully a decision to deploy a new system. Therefore, the enemy should be considered to have time to adjust to our system decisions. A major aspect of the effectiveness of our system is the degree to which it makes such adaptation for the enemy either technologically difficult or economically unattractive.

For example, a study of a proposed system was based on its incorporation into the current force structure. The model for judging the effectiveness of the proposed system was dominated by current or recent conflict situations (e.g., Vietnam, Korea, Europe). In using the model to evaluate the effectiveness of the future system only in the light of these current or recent conflict scenarios, the study failed to consider the steps that the enemy could take to counter the proposed system. (See question 6.)

41. ARE STRAIGHT EXTRAPOLATIONS USED WITHOUT PROOF?

While straight extrapolations (linear relation) often do apply over limited ranges of performance, consumption, or similar planning figures based on averages of large numbers, they rarely apply to effectiveness or cost data.

For example, the relation between the total weight of rations for one infantry division-month and the weight for 10 division-months is a straight extrapolation. The relation between the total cost of the first 100 and that of the first 1,000 units of a new main battle tank is not linear or a straight extrapolation. If a missile system has 10 missiles, costs $1,000,000, and is 50% effective (on some valid measure), then a missile system with 20 missiles, costing $2,000,000, will not be 100% effective but (at best) 75%.

42. ARE DETERMINISTIC AND PROBABILISTIC MODELS USED PROPERLY?

A deterministic model (see Glossary) uses relations of the type, "If A is 5, then B is always 8." A probabilistic model (see Glossary) uses relations of the type, "If A is 5, then B will be 6-10 in 50% of the cases, 4 or 5 in 25% of the cases, and 11 or 12 in 25% of the cases."

Cost-effectiveness analyses frequently require many intermediate calculations involving data. The indiscriminate use of specific values often creates what is in effect a deterministic model. In reality, the majority of the coefficients and planning factors used in models are only averages with variances and different degrees of confidence. The reviewer should try to identify the probable range of variance about the averages that are used as inputs and have at least an intuitive feeling about the confidence of the numerical results.

Additionally, the reviewer should distinguish those cases in which a probabilistic model is needed to reflect the real world situation. Deterministic models are usually appropriate (1) when the planning factor has an insignificant variance, such as weight of rations per day per man for large forces, (2) if the uncertain factor is multiplied by a point value, such as cost of $8,000 to $12,000 per man for a force of 20,000 men, (3) a varying factor is multiplied by a linear function, such as an uncertain flying hour rate (e.g., 2 to 6 hours per day) multiplied by a flying hour cost function of $20 a day plus $40 per flying hour. The deterministic technique is correct in these three cases because it will give the same most probable result as if probabilistic techniques had been applied. Of course, there may still be a problem if the most probable result is not the only one of interest.

Probabilistic models are used where the variables in the problem may assume, at any given time, any one value of a known range and frequency of values, as opposed to deterministic models which use fixed or average values all the time. There are two principal types of probabilistic models: static models using probability statements instead of other values, and dynamic (stochastic) models involving change.

Some stochastic models use random numbers, representing change, to select values from frequency distributions for a given problem. For example, an analysis of a maintenance support organization may include a model which represents the demands for maintenance effort placed on the support organization. Of any 100 jobs (demands), 20 will require 1 manhour, 30 will require 2 manhours, 10 will require 3 manhours, 15 will require 4 manhours, 5 will require 5 manhours, 10 will require 10 manhours, 5 will require 20 manhours, 2 will require 30 manhours, 2 will require 40 manhours, and 1 will require 80 manhours. This information is arranges into a cumulative distribution as shown below:

0-19	:	1 manhours	80-89	:	10 manhours
20-49	:	2 "	90-94	:	20 "
50-59	:	3 "	95-96	:	30 "
60-74	:	4 "	97-98	:	40 "
75-79	:	5 "	99	:	80 "

To represent requests for work, a two-digit random number, say, 37, is drawn (from a table of random numbers or a random number generator); the corresponding value is 2 manhours. The next random number is, say, 84, and the value is 10 manhours. This process continues at some rate (which is probabilistic) and the requests for maintenance are arranged (queued) in the order of simulated requests: 2 manhours, 10 manhours, 4 manhours, and so forth. Available maintenance men would be assigned to requests under various rules, e.g., 1 man to jobs less than 4 hours, 2 men to jobs of 4 to 8 hours, etc. The model would keep track of the time elapsed between generating and completing a request for maintenance. In this manner, the relation of numbers of maintenance personnel and delay can be determined for various assumptions about demand for maintenance effort.

The so-called Monte-Carlo model described above requires, however, a sufficient number of repetitions to obtain adequate information about the range of values of the solution.

A static model using probability statements may, for example, apply in a study on aircraft vulnerability. The probability of survival for a specified time is given by the product resulting from the multiplication of the following probabilities:

Probability of aircraft being detected
Probability of aircraft being acquired by a weapon, if detected
Probability of being hit, if acquired by a weapon
Probability of kill, if hit.

Probability data for each of the probabilities listed above are derived from tests and experiments.

43. IS A ZERO-SUM GAME MODEL USED WHERE IT IS NOT APPLICABLE?

A zero-sum two-person game is a conflict in which there are two sides and the gains of one side equal the losses of the other. Most conflict situations do not justify the use of this type of model. For example, in a hypothetical study, the effectiveness of alternative US tank systems was based on a study of duels between US tanks and enemy tanks. Duel results were based on the losses incurred by each side.

An enemy loss of one tank was equated to a US gain of one tank. The net US gain was used to determine the effectiveness for each alternative.

Our gain is not the enemy's loss. The situation is not always symmetrical. The attacker must move, the defender must inhibit movement. Hence, the objective of a US tank may differ from the objective of the enemy tank. In fact, other alternative concepts might inhibit enemy tank movement more effectively than would a US tank similar to an enemy tank.

44. ARE THE MODELS INTUITIVELY ACCEPTABLE?

Models tend to become mathematical and many are difficult to understand even in their broad aspects. Yet, overly-simplified models tend to become superficial by limitation in choice of detail and omission of important variables. The objective of a good model is to be near enough to reality so that the model outputs can be used to predict some portions of the future with an acceptable degree of confidence.

Models can be tested by determining if they represent correctly known facts and situations not considered in the study. Conversely, if absurd facts and situations are introduced into the model, comparable absurd answers should be produced by the model. If the reviewer is aware of special cases in which there is some indication of the outcome, the model can be tested to determine if the results are in general agreement with the indicated outcome. Another that can be applied, at times, is to vary some of the principal parameters and determine if the model produces results that are consistent and plausible.

45. ARE THE MEASURES OF EFFECTIVENESS IDENTIFIED?

The study should clearly identify the standards or measures used for evaluating the effectiveness of the system or organization under study. If not explicitly stated, the reviewer should attempt to identify these measures from the material contained in the study. The conclusions and recommendations cannot be properly evaluated, particularly when the study is based on equal cost alternatives, without prior evaluation of the measures of effectiveness.

46. IS THE EFFECTIVENESS MEASURE APPROPRIATE TO THE FUNCTION OR MISSION?

The reviewer should satisfy himself that the measures used to evaluate effectiveness are appropriate to the function or mission of the system or organization under study. Failure to use meaningful measures of effectiveness is a major contributing factor to unacceptable studies. Examination of the effectiveness measures requires analysis and sound military judgment. The example below illustrates one use of an effectiveness measure that was not appropriate.

In a study of selected infantry and artillery weapons systems, the measure of effectiveness was a division firepower score. This score was the sum of the firepower scores of the units within the division. The firepower score of a unit was based on sustained rates of fire, effective width of burst, and the fragmentation area of the weapon in comparison with other weapons. Specifically, direct-fire weapons such as rifles were assessed in terms of probable hits per minute against personnel in the open. Mortars and artillery were assessed in terms of maximum effective range and lethal area coverage per minute.

This use of a firepower score was wrong for a number of reasons. Primarily, it failed to differentiate between the effectiveness of weapons when used for neutralization and when used to produce casualties. For neutralization, the effectiveness is strongly dependent on burst rate of fire, incipient damage area produced by the burst, and ability to maintain fire over the required time (the latter a function of weapon characteristics and ammunition requirements). On the other hand, casualty production depends strongly on the probability of hit, which in turn depends on target acquisition and weapon guidance or accuracy. Thus, in this case, several measures must be used to have a valid analysis.

The total division firepower score used in the study also assumed an inexhaustible and uniform supply of ammunition regardless of whether the weapon was a rifle company machine gun or a division general support artillery cannon.

47. DO THE EFFECTIVENESS MEASURES IGNORE SOME OBJECTIVES AND CONCENTRATE ATTENTION ON A SINGLE ONE?

In the measurement of effectiveness, the reviewer should watch for any tendencies to concentrate on only one or two objectives. Such a situation indicates an unstated assumption that other objectives are unimportant. The resulting conclusions and recommendations, if implemented, may cause an imbalance and reduce the capability to achieve other objectives.

For example, a study indicates that the most vulnerable element in a line of communications system are the bridges in a rail network and measures effectiveness of deployment of given air defense units by degree of protection afforded railway bridges. In evaluating the overall effectiveness of the air defense deployment, the study fails to consider that the vulnerability of other elements in the line of communications system may be greatly increased by the redeployment of the air defense.

A possible test for effectiveness measures suspected of concentrating on a single objective is to evaluate them against a hypothetical obviously absurd weapon or device that does only one job. Valid measures of effectiveness should show an absurd hypothetical weapon or device in its true light.

48. ARE PERFORMANCE MEASURES MISTAKEN FOR EFFECTIVENESS MEASURES?

Measures of performance characteristics are sometimes misconstrued as measures of the ability of the system or organization to accomplish its function. Performance characteristics may contribute one of the many inputs required to achieve the effectiveness of the system or organization as a whole. For example, the speed of movement or mobility of a unit is only one aspect of the unit's capability to accomplish its function. The speed at which a unit can attack the enemy is not in itself a measure of the ability of the unit to defeat the enemy. The weapon with the smaller CEP is not necessarily the more effective weapon; the relation of lethal radius to CEP may be more significant. Other factors that must be also considered in weapon effectiveness include target acquisition, weapon guidance, and target size.

49. IS THE EFFECTIVENESS CALCULATED ON THE BASIS OF EITHER A COOPERATIVE ENEMY OR AN OMNIPOTENT ENEMY?

Neither basis is valid. The enemy should be expected to adjust his decisions to our own planning as much as his resources permit. An unstated assumption that the enemy is inflexible in the face of our changes is a common error in cost-effectiveness studies.

For example, a counter-guerrilla study used a scenario in which the hostile guerrilla forces retreat to a mountain redoubt to be surrounded by US troops air-landed by helicopters. This scenario makes conventional tactics palatable in counter-guerrilla warfare, but is hardly realistic. A capable guerrilla leader should not be expected to use such disastrous tactics. Adaptation of enemy tactics (e.g., rapid dispersal) in face of the new US capability for air landing is certainly feasible. A comparable adaptation to the enemy capabilities was illustrated during World War II. German air defense analyses prior to that war were based on the attacking aircraft using certain altitudes that were optimum for the air defense batteries. Allied bomber aircraft did not oblige and avoided the "optimum" altitude range.

Some studies assume maximum future enemy capability in all weapon areas. The enemy cannot simultaneously maximize all of this capabilities if constraints in physical resources and budgets are present, particularly in the case of peacetime budgets. If he maximizes his strategic forces, he will have to limit his tactical capabilities, and vice versa. Alternatives, where appropriate, should be pitted against a variety of enemy postures and the choice should make none of these postures particularly attractive to the enemy.

In theory, the enemy can counter every system we design and our effectiveness will not be sufficiently high to warrant a positive decision. The real question is: how much does it cost the enemy in time and resources to effect a direct counter? If the price is very high he will probably seek other lesser alternatives. (See question 6.)

50. IS THE EFFECTIVENESS MEASURED BY ANALYSIS OF WARGAMES?

When effectiveness is measured by analysis of wargames the reviewer should look to sensitivity analysis of the results. As a rule, wargames are a questionable means for measuring effectiveness because of the difficulty of testing the sensitivity of the results. To do so means challenging the effect of changes in players, referees, communications, as well as payoff functions. (See question 18.)

51. IS THE EVALUATION OF EFFECTIVENESS BASED ON STRAIGHT EXTRAPOLATION?

Occasionally a study may evaluate effectiveness by straight (linear) extrapolation from the measurement of effectiveness of a small unit. For example, a hypothetical study may show that 6 riflemen can destroy 10 targets. An extrapolation that states 100 targets can be destroyed by 60 riflemen is not justified without supporting evidence. The variables in target and fire distribution are not necessarily the same

in both cases. Further, in a force of 60 riflemen the percentage who will actually fire at targets may not be the same as for a force of 6 riflemen.

Another error in straight or linear extrapolation is disregard of the element of diminishing returns or marginal utility. For example, 200 missiles do not signify twice as much effectiveness as 100 missiles if there are only 50 targets. Furthermore, all targets are not of equal value or importance.

52. ARE THE OPERATIONS OF OTHER SERVICES IGNORED?

In measuring the effectiveness of a system or organization, consideration must be given to the operations of other Services, where appropriate. Failure to do so is the equivalent of making the erroneous unstated assumption that only the Army will participate in the operation. For example, the measurement of effectiveness of Army air defense operations must consider the communications, command and control, and IFF aspects of operations with the U.S. Air Force and allied air forces. Further, the effectiveness of certain Army operations is dependent upon the degree of air superiority achieved by the Air Force. The ability to achieve this air superiority and the degree of dependence upon it should be examined. (See question 10.)

53. IS THE IMPACT ON OTHER ARMY OPERATIONS IGNORED?

In measuring the effectiveness of a system or organization, the effects on other Army operations should be considered. For example, the use of tactical nuclear weapons in a certain manner may accomplish its function by stopping enemy ground movement. However, the judgment of the effectiveness of the system should also examine the effect on the ground movement of U. S. units. In the same manner certain protective clothing may be effective against enemy chemical agents. However, the clothing may cause such body heating that it can only be worn for very short periods.

54. ARE SOME ASPECTS OF EFFECTIVENESS INCOMMENSURABLE OR UNMEASURABLE?

The reviewer should examine carefully the treatment of incommensurables and unmeasurable aspects of performance in the total measurement of effectiveness. Misleading measures of effectiveness are now often obtained by quantifying such aspects as morale, or leadership. At times, the only practicable solution may be a qualitative discussion of these factors.

55. DOES THE EFFECTIVENESS OF A FUTURE SYSTEM TAKE INTO ACCOUNT THE TIME DIMENSION?

The effectiveness of proposed future systems is often dependent upon when they can be available for operational use and the total operational life span of the systems. In examining the effect of the time dimension upon effectiveness, particular attention should be given to (1) the time between the present and the initial operational availability of the complete system, and (2) the latter part of the system operational life span.

For example, the effectiveness of Weapon Y, deployable in 1972, is compared with that of the current Weapon X. Weapon Y is judged to be more effective and requires entirely new support equipment not compatible with that of Weapon X. This equipment cannot be operationally available until 1974. It is very possible that the changeover from X to Y implies a dip in effectiveness during the 1970-74 interval. The old weapon is becoming obsolete and the new one is not fully effective. A quick fix means may be needed to bridge this gap and must be charged to the cost of X and Y.

In another case involving the time dimension, Weapon B, deployable in 1972, replaces Weapon A and is designed to perform the same mission more effectively. It is stated to have an operational life of 15 years. Effectiveness is calculated on the basis of the 1972 environment. In the 1972 to 1987 period (the operational life of B) the international environment, and hence the missions may undergo major changes. In fact, the mission for which A is designed may already be on the decline. Effectiveness is not always constant but often must be related to time.

It is necessary to recognize that missions do not remain fixed. Effectiveness should not be evaluated on the basis of either a specific probability of the continuity of the mission or of a specified new mission. Rather, the system should be judged on its ability to adjust to such changes.

Similar comments apply with respect to changes in technology. Breakthroughts cannot be predicted very successfully. Nevertheless, certain trends are noticeable. For example, anti-tank weapons have improved more rapidly than tanks since World War II. The sensitivity of the system to jumps in technology is a vital input to effectiveness evaluation of massive long lifetime systems.

56. ARE EXPECTED AND AVERAGE VALUES USED INCORRECTLY TO MEASURE EFFECTIVENESS?

It is an error to employ an expected value or average as part of a measure of effectiveness <u>if the objective really requires a specified</u>

minimum. In such a case, the possible variances, or dispersions about the average, constitute an unacceptable risk for any single event. This risk is unacceptable even though over many events the results will average out to the expected value.

For example, assume that at the same cost, air defense System A destroys from 0 to 99 of 100 approaching enemy aircraft but on the average destroys 50. System B, on the other hand, destroys from 25 to 35 of 100 approaching aircraft with an average destruction of 30. The risk associated with the possibility that, in any given individual attack by 100 aircraft, System A may not destroy any aircraft at all, whereas System B can be counted on to destroy at least 25 aircraft, makes A an unacceptable system, if the objective is air defense. If the objective were destruction of as many enemy aircraft as possible over some period of time but without regard to their damage to us, (an unlikely objective) System A would be preferred.

57. IF QUANTITATIVE MEASURES OF EFFECTIVENESS ARE UNATTAINABLE, IS A QUALITATIVE COMPARISON FEASIBLE?

There are times when the effectiveness of a system or organization cannot be presented adequately in quantitative terms. This situation is common in comparison of general purpose forces such as in studies of alternative divisions. A study that assigns numerical values to effectiveness of general purpose forces should be examined carefully.

One study compared alternative divisions in terms of numerical scores. Each of the six basic factors (firepower, intelligence, mobility, command/control/communications, logistics, survivability) was given a numerical value and these values were summed for each alternative. The resulting sums were compared as effectiveness measures. These numerical values are likely to be meaningless because the six basic factors are inputs and not objectives. They combine in undetermined ways to make up the effectiveness of tactics. The tactics, in turn, combine to evolve strategies. For example, deception tactics strongly involve the basic building blocks of intelligence, command/control/communications, and mobility. However, this does not mean that we can simply add up so-called scores of these three basic factors and thereupon compare the deception capability of various alternatives.

A qualitative comparison is possible, however. Various pertinent aspects can be described and characterized by "yes-no" or "good-fair-poor." A tabular comparison can be useful in weeding out some alternatives. It may justifiable to say that Alternative A is more effective than B (denoted $\frac{A}{B}$) in a certain characteristic, even if it is not known whether A is $1\frac{1}{2}$ times or twice as effective as B. If it can be deter-

mined that $\frac{A}{B}$ and $\frac{A}{C}$ we have a partial ordering $\frac{A}{B,C}$ i.e., we cannot distinguish between B and C but either is inferior to A. We may obtain a grouping as follows:

$$\frac{\frac{A}{B,C,D}}{E}$$

Let us reconsider the example of the deception tactic. Its key ingredients are mobility, command/control/communications, and intelligence. Suppose we know that Division A is more mobile than B, therefore, $\frac{A}{B}$. If we should arrive at the same ranking for the other two basic factors, then we conclude that $\frac{A}{B}$ is also true for the deception tactic. On the other hand, it may be that $\frac{A}{B}$ for mobility and $\frac{B}{A}$ for intelligence. Then no statement can be made for the relative ranking of A and B for the deception tactic.

In this manner, tactics of interest can be investigated and valid partial orderings of alternatives obtained. We may find dominant alternatives. Suppose we obtain:

Mobility	Intelligence	Command, Control, Communications
$\frac{A,B}{\frac{C}{D,E}}$	$\frac{E,A}{B,C,D}$	$\frac{E}{\frac{A,B,C}{D}}$

We have now learned that D is dominated by A for all three basic factors, and hence for the deception function. So D can be eliminated if all alternatives have equal cost. It should not be assumed that rankings of alternatives with respect to the tactical level can only be derived by buildup and integration from the basic level. There may be direct qualitative comparisons with respect to, say, deception effectiveness as a result of wargames or field exercises. A combination of both buildup and direct approaches would probably prove most fruitful.

The reviewer should recognize that while cost-effectiveness analysis is performed preferably by quantitative analysis, there are limits to suboptimizing or idealizing the problem to make it amenable to quantitative analysis. When carried too far, the quantitative results are often only of academic interest and offer little or no help to the decision maker.

58. IS THE EFFECTIVENESS SENSITIVE TO CHANGES IN ASSUMPTIONS?

The effectiveness derived in most studies is usually dependent to a degree on the assumptions The reviewer should isolate the degree of

dependence and determine if it is acceptable. Generally, a good study will isolate this dependence, where it exists, and lay out the degree of dependence by various kinds of sensitivity or contingency analysis. The assumptions that most commonly influence effectiveness and are often not subjected to contingency analysis concern the locale, the time and level of warfare, and enemy forces and tactics.

A slight change in any of these assumptions may produce significant changes in the effectiveness measured. For example, additions of a new ECM band width to the enemy's capability may drastically degrade an otherwise outstanding U.S. system. (See questions 5 and 6.)

59. ARE THE CRITERIA IDENTIFIED?

The criteria, or tests of preferredness, are the basis for the conclusions and recommendations. The criteria should be stated specifically and clearly. If this is not the case, the reviewer should attempt to identify the criteria from the material contained in the study. When this does not prove possible, consideration should be given to having the study returned for further clarification. This is particularly important if the study is also to be reviewed by agencies outside the Army.

60. ARE THE CRITERIA CONSISTENT WITH HIGHER ECHELON OBJECTIVES?

No matter what the concern of a study, the subject falls into a larger framework. For example, problems of air defense of the CONUS are aspects of the larger problem of restricting possible damage to the CONUS to certain levels. The design of artillery systems is part of the larger problem of design of land battle forces. Therefore, the reviewer must determine if the criteria used in a study are consistent with higher level objectives. This requires good military judgment and the necessity to examine the larger context of the problem. If the study criteria are not consistent with the objectives at the higher level then the wrong problem may be solved. Overall Army objectives are contained in documents such as the Basic Army Strategic Estimate (BASE), Army Force Development Plan (AFDP), Army Strategic Plan (ASP), and the Combat Developments Objective Guide (CDOG).

An example of incorrectly chosen criteria is illustrated in the use of mobility as the sole criterion in the selection among different organizations. A study could conceivably demonstrate that organization A can be made more mobile than organizations B and C with a lesser expenditure of resources. Yet A may not be the preferred organization because the mobility was achieved by degrading other factors that contribute to the higher objective of efficient control of conflict situations (e.g., firepower, sustainability, etc.).

61. ARE THE CRITERIA TOO GENERAL?

Generalized criteria are suspect. For example, a study may state that the criterion is "the system with maximum military worth" or the "best system." Such generalizations are meaningless and cannot be related to the analysis as can a good criterion such as "the minimum cost of maintaining a [specified] level of transport capability over a [specified] time span."

62. ARE THE CRITERIA OVERDETERMINED?

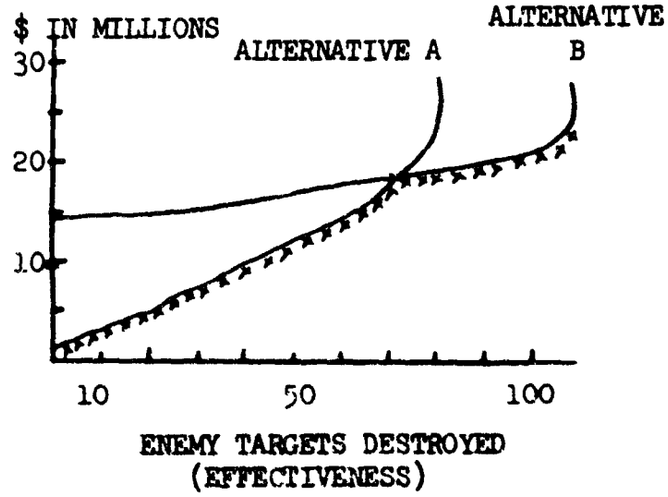
Overdetermined criteria lead to erroneous conclusions. A criterion that states "to maximize the damage to the enemy while at the same time minimizing the cost to the U.S." or "causing the maximum amount of casualties with the least expenditure of ammunition" suggests that something can be obtained for nothing. It is impossible to maximize gain and simultaneously minimize cost. It is not possible to increase effectiveness without some increase in resources (cost). The minimum cost is to do nothing--and achieve no effectiveness. Occasionally it may turn out that system A is both more effective than system B and costs less. However, system A will not be both more effective and cost less when compared with <u>additional</u> alternatives. The danger of using an overdetermined criterion, such as the one described, is that it leads to invalid compromise criteria by using some erroneous constraint on effectiveness or cost in an effort to make an impossible test seem feasible.

63. ARE GOOD CRITERIA APPLIED TO THE WRONG PROBLEMS?

At times a valid criterion for one element of the problem in incorrectly applied to the total problem. For example, a hypothetical study involving proposed surveillance aircraft shows that aircraft A offers greater mission flexibility than aircraft B at the same cost and is therefore preferred. In this case, the choice of aircraft is not the real problem. The subsystems carried by the aircraft are really more crucial. The all-weather sensor effectiveness and avionics cost may even determine whether there should even be an aircraft A or B.

64. IS THE ABSOLUTE SIZE OF GAIN OR COST IGNORED?

If the absolute size of the cost of a system alternative, or the effectiveness to be achieved by it, is not given or is incorrect, the analysis often leads to wrong conclusions and recommendations. For example, cost-effectiveness curves for two hypothetical system alternatives is given below:



In this situation, at low levels of effectiveness, alternative A is preferred (up to about 70 enemy targets destroyed); at larger levels of effectiveness, alternative B is preferred (from about 70 to 110). If the capability to destroy more than 110 enemy targets is to be achieved, then neither alternatives A or B is preferred or even acceptable. The crucial question is how many enemy targets are required to be destroyed. If the number of enemy targets to be destroyed or cost limits are not indicated, there is no real basis to recommend either alternative A or B, or some other alternative.

Either the study should be based on an absolute size of gain or cost required or the study should present a cost-effectiveness curve (or points) from which decisions can be made. If the study presents a cost-effectiveness curve as shown above, the envelope (indicated by line of X's in the graph) along the bottom says, "This is a curve which gives the most for the resources expended, and other things have to be taken into consideration at higher levels to determine what the absolute gain (number of targets destroyed) should be or the maximum resources (cost) that can be made available."

At times, studies ignore absolute size of gain or cost and use effectiveness-to-cost ratios. The flaw in the use of such ratios is the absence of any specified level of effectiveness required or resources available as discussed above. If the level of activity is fixed, a ratio may be useful in ranking among alternative systems. However, the effectiveness-to-cost ratio criterion is often applied when the level of activity is not fixed. For example, in the graph above alternative A destroys 10 enemy targets for $15 million, and alternative B destroys 100 enemy targets for $25 million. If only this information were converted to effectiveness-to-cost ratios, alternative A would have a ratio of 10:1 and alternative B, 4:1. Which is the preferred? If one did not look at the absolute level of effectiveness required to achieve the military task but only at the effectiveness-to-cost ratio, then alternative A would be preferred. The selection of alternative A on this basis may be correct, but only by coincidence and is obviously wrong when the system must be capable of destroying more than 70 targets.

Until the absolute level (magnitude) of effectiveness or the absolute level (magnitude) of the cost is specified the preferred alternative cannot be determined. The effectiveness-to-cost ratio can be misleading and, at times, a dangerous criterion.

CONCLUSIONS AND RECOMMENDATIONS

65. ARE THE CONCLUSIONS AND RECOMMENDATIONS LOGICALLY DERIVED FROM THE MATERIAL CONTAINED IN THE STUDY?

The conclusions and recommendations should be derived logically from the material contained in the study. Some studies, unfortunately, draw conclusions based on previous studies and materials that are not fully documented within the study (mention in a bibliography is hardly sufficient). If input from another study is essential, it should be documented and explained in detail. This requires, at least, a statement as to validity, scope of application and uncertainty which is associated with the particular input.

The determination of whether the conclusions and recommendations follow logically from the material in the study is a matter of judgment by the reviewer. In making this judgment, the reviewer should consider whether other prudent study agencies would probably arrive at substantially the same conclusions and recommendations given only the material contained in the study.

66. HAVE ALL THE SIGNIFICANT RAMIFICATIONS BEEN CONSIDERED IN ARRIVING AT THE CONCLUSIONS AND RECOMMENDATIONS CONSIDERED?

Sometimes a study fails to consider all the pertinent ramifications in arriving at the conclusions and recommendations. These unconsidered ramifications may either influence the validity of the conclusions and recommendations of the study or the decisions to be made as a result of the study. These ramifications are often referred to as "spillovers." For example, if a hypothetical study recommended adoption of an engine requiring a new type of fuel, the Army supply system to include supply, storage and transportation operations would be affected. Spillover effects are not always negative. For example, the adoption of dehydrated rations to achieve greater shelf-life may also reduce construction and transportation costs because of the smaller unit volume of dehydrated food.

Other ramifications that are sometimes neglected are factors that should be considered jointly with the problem under study. At times, consideration of such joint decisions could affect the conclusions and recommendations of the study. For example, a study may recommend adoption of a new weapon system to fulfill a certain function. However, the study may neglect to examine the maintenance support and the maintenance units that would have to be in existence concurrently with the proposed weapon system. The resources required to organize and maintain the maintenance system will influence decisions on the proposed weapon system.

If significant ramifications are uncovered that are not adequately considered, the reviewer should, if possible, determine the effects of these ramifications on the conclusions and recommendations. (See question 2).

67. ARE THE CONCLUSIONS AND RECOMMENDATIONS REALLY FEASIBLE IN THE LIGHT OF POLITICAL, CULTURAL, POLICY OR OTHER CONSIDERATIONS?

In reviewing the conclusions and recommendations of a study, it is necessary to be cognizant of the real world in which the Army must operate. At times some recommendations of a study may appear to be eminently feasible from a strictly economic or military view, but really are not so in the light of other considerations that influence military operations. For example, a particular toxic chemical munitions system may be demonstrated to be superior, considering cost and effectiveness, to a high explosive munitions system for accomplishing a certain function. However, because of national policies on employment of toxic chemicals, the adoption of the high explosive munitions system may be the only feasible solution.

The reviewer should also consider the impact of policies that may not have been known to the agency that prepared the study or were promulgated too late to influence the study.

68. ARE THE CONCLUSIONS AND RECOMMENDATIONS RELATED TO THE LIMITATIONS OF THE STUDY?

In evaluating conclusions and recommendations, the reviewer should bear in mind the limitations of the study. Studies, as a rule, have varying degrees of limitations. The more common types of limitations include inadequate data base, criticality of assumptions, criticality of uncertainties and validity of cost and effectiveness models. While the limitations may be treated within the study, the dependence of the conclusions and recommendations on the limitations is sometimes neglected. For example, the study conclusions and recommendations may depend upon the validity of particular assumptions but this relation may not be pointed out.

It may be advisable for the reviewer to refresh his memory on the study limitations, particularly when the study is voluminous, before evaluating the conclusions and recommendations.

69. DO THE CONCLUSIONS AND RECOMMENDATIONS INDICATE BIAS?

Studies sometimes unwittingly reflect bias because of parochial or institutional interests. To assist in detecting bias, the reviewer should consider the relation of the agency that prepared the study and the effects of the implementation of the study recommendations. If such implementation does not appear to further what are generally considered to be the particular interests of the preparing agency, then one occasional form of bias is probably not present. Another test for bias is to judge whether substantially the same conclusions and recommendations would be reached, based on the material in the study, by another study agency. Bias is often displayed by arbitrarily excluding certain reasonable alternatives, maximizing selected enemy capabilities, treating significant uncertainties as assumptions, and in selection of effectiveness criteria.

A relatively minor form of bias is sometimes found in the use of prejudicial adjectives. Unnecessarily referring to all Air Force fixed wing aircraft as "long take off and landing" aircraft is an example. This type of bias may be prejudicial to the interests of the Army when the study is reviewed by non-Army agencies.

70. ARE THE CONCLUSIONS AND RECOMMENDATIONS BASED ON EXTERNAL CONSIDERATIONS?

At times, recommended selections among alternatives must be made in the face of great uncertainty. A study may find that several alternatives exhibit similar cost-effectiveness, but the results are very sensitive to the values assigned to the inputs. In this situation some studies arrive at conclusions and recommendations based on considerations other than those studied. In other words, the study agency is stating that after having made the analysis, the application of the criteria does not lead to preference, but indifference, among the alternatives and therefore the issue was decided on the basis of other unstudied criteria. In situations of this kind, when recommendation of an alternative is necessary, sensitivity to new criteria must be fully studied.

71. ARE THE CONCLUSIONS AND RECOMMENDATIONS BASED ON INSIGNIFICANT DIFFERENCES?

At times a study will present one alternative as having the highest value of effectiveness of the measures applied to all alternatives. The difference in effectiveness among the "optimum" alternative and the other alternatives should be examined. If the differences are relatively slight and probably no greater than the uncertainties in the data, then other grounds should also be demonstrated for selecting among the alternatives that are close in effectiveness.

72. IF PRIORITIES ARE LISTED, ARE THEY STATED MEANINGFULLY?

Conclusions and recommendations often list items of equipment in order of priority of recommended procurement or adoption. The use of this technique without explanation, particularly for materiel, is often poor because it provides no basis for a decision. For example, a study may conclude that in order to accomplish certain functions, infantry units should be equipped with specified items of equipment that are listed in order of priority. Assume that the items found necessary by the study for infantry units to accomplish the required functions are, in order of priority:

(1) Seven League Boots
(2) Disintegrator Ray Pistol
(3) Universal Viewing Device
(4) Camouflage Suit (makes the wearer invisible)

Although the study concluded that all of these items are required, the listing of priorities without any quantitative considerations could have any of these meanings:

a. Buy all of the Seven League Boots required. Then, as resources are available, buy all of the Disintegrator Ray Pistols required. Continue down the list of priorities in this manner until the available resources are exhausted. This meaning also infers that even though all 4 items are required, the Army can do without the lower priority items if sufficient resources are not available to procure them all. For example, with limited resources it is better to have all Seven League Boots and none of the other items rather than some of each item.

b. Buy all 4 items at once but spend more money on Seven League Boots than on Disintegrator Ray Pistols and even less amounts on Universal Viewing Devices and Camouflage Suits.

When faced with this kind of situation, consideration should be given to returning the study to the preparing agency for further recommendations on how much should be allocated to each item for various budget levels, either given or assumed.

73. ARE THE CONCLUSIONS AND RECOMMENDATIONS INTUITIVELY SATISFYING?

When the conclusions and recommendations of the study are not intuitively satisfying, the reviewer should attempt to isolate the cause. If the study fails to demonstrate by data, models and other means that the reviewer's intuition was wrong, then further examination is required to determine if some subtle considerations have not been considered because of oversimplification or other reasons which the reviewer intuitively knows are pertinent.

GLOSSARY

Alternative

One of several different ways of achieving a desired capability.

Building Block Cost

One kind of a rough estimate of the cost of an alternative for planning purposes. The estimate is not time-phased and does not provide for variations such as in the manning of the unit or cost-quantity relationships.

Contingency Analysis

Repetition of an analysis with different qualitative assumptions such as theater, or type of conflict, to determine their effects on the results of the initial analysis.

Commensurability

The capability of two qualities or values to be measured by a meaningful relevant common index. For example, machine guns and rifles are commensurable either in dollar cost or in effectiveness, e.g., enemy casualties. However, machine guns and friendly casualties are not commensurable in terms of dollars.

Cost Analysis

The analysis and determination of cost (total resource implications) of interrelated activities and equipments to determine the relative costs of alternative systems, organizations, and force structures. Cost analysis results are not designed to have the precision required for budget purposes.

Cost-Effectiveness Analysis

The quantitative examination of alternative prospective systems for the purpose of identifying the preferred system and its associated equipment, organizations, etc. The examination aims at finding more precise answers to a question and not at justifying a conclusion. The analytical process includes trade-offs among alternatives, design of additional alternatives, and the measurement of the effectiveness and cost of the alternatives.

Cost Estimate

The estimated cost of a component or aggregation of components. The analysis and determination of cost of interrelated activities and equipments is cost analysis.

Cost Estimating Relation (CER)

A numerical expression of the link between a physical characteristic, resource or activity and a particular cost associated with it; e.g., cost of aircraft maintenance per flying hour.

Cost Model

An ordered arrangement of data and equations that permits translating physical resources into costs.

Criterion

Test of preference. For example, highest effectiveness (expected wartime capability) at the same net future peacetime cost of ownership.

Deterministic Model

A model that permits no uncertainty in the magnitudes of either inputs or outputs. An example from gunnery is:

$$W = \frac{RM}{1000}, \text{ where}$$

W is the lateral distance at range R; R is the range and M is the angular measure in mils of the arc subtended by W at range R. For any set of given values for R and M there is one and only one value for W. Many deterministic models use an average as a constant value input.

Force Structure Analysis

The analysis of proposed forces to obtain a picture of resource implications for planning.

Force Structure Costing

The determination of the resource implications (manpower, materiel, support, training, etc.) in dollar terms of a given force structure or change to it.

Incommensurability

The lack of capability of two qualities or values to be measured by a meaningful relevant common index. (See Commensurability)

Incremental Cost

The net additional costs that would result from choosing a particular alternative as compared to a continuation of the present program.

Individual System (Organization) Costing

The determination of the total resource implications of a system (organization) without consideration of the interaction of the system (organization) as part of a force structure.

Investment Cost

The cost beyond the Research and Development phase to introduce a new capability into operational use.

Learning Curve

The cost-quantity relationships for estimating costs of equipment. Generally used to predict or describe the decrease in the cost of a unit as the number of units produced increases.

Linear Programming

A mathematical method used to determine the best use of limited resources to achieve a desired result when the limitations on the resources are expressed by simultaneous linear relations ($x = a + by$). Linear programming is applicable to problems involving resource allocations and scheduling. For example, linear programming has been used to determine the best scheduling of facilities for a given number of students taking courses

requiring different kinds of classrooms, shops, and ranges where there are limitations on the number of instructors and on the numbers and sizes of classrooms, shops, ranges.

Model

Relations used to portray real or expected conditions, actions or effects in order to predict the outcome of actions. For example, a road space and time length nomograph (FM101-10, page 131) is a mathematical and graphic model. It portrays real conditions, e.g., average road spaces and time lengths under certain conditions. It is used to predict the outcome of an action, e.g., determination of road space and time length and so forth resulting from the movement of a certain force under certain conditions. A service maneuver could be considered a non-mathematical model. It portrays the expected world (combat) as realistically as circumstances permit in an effort to foresee, even to a limited extent, the outcome of certain actions (use of certain organizations, tactics, and equipment).

Monte Carlo Technique

Used to solve probability problems by employing sampling to estimate the answer to a precise mathematical problem. A "game" or model is formulated so that the average of the results of a large number of plays of the game or model is approximately the number being estimated. Individual plays of the game or model are often used to determine the probability of a random event. For example, in the study of the probable vulnerability of a target, the Monte Carlo technique is often applied to the error of the attacking weapon. A model is prepared containing random numbers with the same distribution as CEI values. A selection of a random number (random event) gives the probable CEP for the simulated firing of the weapon. (See question 42)

Objective

The purpose to be achieved or the position to be obtained. Objectives vary with the level of suboptimization of the study.

Operating Cost

The recurring cost required to operate and maintain an operational capability.

Parameter

An element of a problem that may be either a constant or a variable. For example, the demand for and availability of parts are parameters in some logistics problems.

An analysis conducted with assumed instead of expected or actual values. In the absence of data from experiments, or other sources, parametric analyses are used to examine a problem, to identify sensitive parameters, and to obtain reasonable approximations of final results (upper and lower bounds). In a parametric analysis, a range of values for each parameter are assumed which will bracket the expected values of that parameter, and a solution to the problem obtained for each set of assumed parameter values. In summary, a parametric analysis answers the figurative question: "If the values of the parameters were such and such, then what will the results be?"

Peacetime Costs

The costs associated with developing, buying, and maintaining a capability for potential war during peacetime. Included in these peacetime costs are the resource implications of buying and maintaining a war reserve.

Probabilistic Model

A model that makes allowances for randomness in one or more of the factors that determine the outputs of the model. For example, an inventory model that optimizes an inventory policy to avoid inventory shortages is probabilistic if it takes explicit account of uncertainty over time, in the distribution of demands on the inventory. On the other hand, the model would be deterministic if it assumed that the rate of demand against the inventory is always the same (usually the estimated average demand). In this example, a deterministic model would most probably give answers that would lead to bad inventory policies. However, there are times when the use of a deterministic model in a probabilistic situation does no harm. (See question 42)

Queuing Theory

A theory that deals with the analysis of costs and effectiveness when items appear with some randomness for processing at a facility with a capacity for processing simultaneously fewer items than may be waiting at a given time. The costs are costs of waiting and of providing the capacity to reduce the amount of waiting. Examples of queuing problems

are: (1) determination of a number of checkout counters at a supermarket that minimizes the sum of costs of customer dissatisfaction if they must wait in line and costs of providing additional checkers; (2) determination of the capacity of communication systems to minimize the costs of communications capacity and of delays in the processing of messages.

Research and Development (R&D) Costs

The cost of developing a new capability to the point where it is ready for procurement for operational units.

Resource Impact

The cost of adopting a course of action stated in measurable terms. Resource impacts cannot always be reduced to dollar terms.

Risk

As used in cost-effectiveness analysis and operations research, a situation is characterized as risk if it is possible to describe all possible outcomes and to assign meaningful objective numerical probability weights to each one. For example, an action might lead to this risky outcome: a reward of $10 if a "fair" coin comes up heads, and a loss of $5 if it comes up tails. Another example, 50% of all missiles fired can be expected to land within one CEP of the target.

Sensitivity Analysis

Repetition of an analysis with different quantitative values for cost or operational assumptions or estimates such as hit-kill probabilities, activity rates, or R&D costs, in order to determine their effects for the purposes of comparison with the results of the basic analysis. If a small change in an assumption results in a proportionately or greater change in the results, then the results are said to be sensitive to that assumption or parameter.

Spillover

The effects of one system or organization upon another system or organization.

Stochastic Process

The statistical concept underlying the prediction of the condition of an element of a larger group when the probable average condition of the larger group is known. For example, assume that an armored division, under certain circumstances, has on the average a certain number of tanks deadlined for unscheduled maintenance. The probability that any given tank under the same circumstances, will be deadlined for unscheduled maintenance on a specific day is described by a stochastic process.

Suboptimization

Optimization refers to a selection of a set of actions that maximize the achievement of some objective subject to all of the real constraints that exist. For example, one may optimize a choice of weapons for achieving certain objectives of a decision but within the given constraint of a certain maximum cost of a division. But one suboptimizes on achievement of the division objective if he is given discretion only over the amount and kind of armor and is given a maximum amount of money to spend on armor. The objective he maximizes directly may be only the mission of armor in the division's objective. Such a suboptimization will yield something inferior to an optimized expenditure on different kinds of armor if the total budget for armor given to the suboptimizer is really not optimal, or if there are interdependencies between decisions on armor and decisions on other things that are outside the discretion of the person suboptimizing on armor.

Sunk Cost

The costs expended in the past and which are now irrelevant to present and future decisions.

System

An integrated relationship of men, equipment and methods appropriately organized to accomplish defined tasks.

System Analysis

There is no commonly accepted definition for this term. It is often used synonymously with cost-effectiveness analysis. Other definitions used in engineering, management, and computer system design are:

a. (Engineering) Part of the preliminary design leading to selection of preferred design approaches.
b. (Management) Study of methods for obtaining desired results. Emphasizes reporting and control techniques.
c. (Computers) Part of the design of systems of computers and peripheral equipment for miscellaneous uses.

Time-Phased Cost

A presentation of the cost results broken down by the time period in which the costs occur rather than a single total cost figure.

Total Obligation Authority (TOA)

The cost allocated to a given system or organization. This cost when related to a specific time period, for example a year, represents obligations that can be incurred during that year and not necessarily expenditures. The total obligation authority for a specific year to furnish a house is the cost of what can be ordered during that year even if deliveries and payments are made in later years.

Uncertainty

A situation is uncertain if there is no objective basis for assigning numerical probability weights to the different possible outcomes or there is no way to describe the possible outcomes. For example, the probability of a foreign nation continuing to furnish the U.S. with base rights is an uncertainty.

Wartime Costs

Those costs associated with producing and delivering resources to the theater after the war has started.

SELECTED QUESTIONS

1. Is the problem stated the real problem? (See Page 13)

4. Are the assumptions unduly restrictive? (See Page 15)

12. Are any feasible and significant alternatives omitted? (See Page 19)

13. Is the study adequately documented? (See Page 20)

14. Are the facts stated correct? (See Page 20)

22. Are the cost estimates relevant? (See Page 24)

23. Are incremental costs considered? (See Page 25)

31. Is an amortized cost used? (See Page 29)

37. Are the models adequately identified and explained? (See Page 32)

44. Are the models intuitively acceptable? (See Page 37)

46. Is the effectiveness measure appropriate to the function or mission? (See Page 38)

57. If quantitative measures of effectiveness are unattainable, is a qualitative comparison feasible? (See Page 43)

60. Are the criteria consistent with higher echelon objectives? (See Page 46)

66. Have all the significant ramifications been considered in arriving at the conclusions and recommendations considered? (See Page 49)

73. Are the conclusions and recommendations intuitively satisfying? (See Page 52)

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NOTE: A number of publications listed above are available through the Defense Documentation Center (DDC). The DDC will send single copies of requested publications to government agencies and to non-government organizations having Department of Defense contracts and an approved Field-of-Interest Register on file at DDC. Publications should be ordered by DDC Document (AD or ATI) numbers on DDC Form I Complete instructions and the forms necessary for requesting documents are contained in "DDC Service Information and Forms" which may be obtained from:

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