HEADQUARTERS

UNITED STATES ARMY
COMBAT DEVELOPMENTS COMMAND

FORT BELVOIR, VIRGINIA

USACDC PAMPHLET NO. 71-1

FORCE DEVELOPMENTS
THE MEASUREMENT OF EFFECTIVENESS

JANUARY 1973

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FOREWORD

This Pamphlet provides assistance to the military operations analyst and guidance for the combat developments study officer in the selection and use of appropriate measures of effectiveness to evaluate and compare land combat systems and subsystems. The scope of the pamphlet covers the development, formulation, and use of measures of effectiveness in the combat developments process.

Included are the roles of measures of effectiveness in the analysis, test and experimentation, and documentation of Army doctrinal, organizational and materiel systems concepts. The critically important role of measures of effectiveness in the decision process for combat systems development is highlighted. Emphasis is on the methodology to develop measures of effectiveness - - a process which can best be described, at present, as an art trying to become a science. Additional emphasis is placed upon the impact that selective measures of effectiveness can have on modeling, military judgement, and the degrees of various sorts of risks which may be involved in conclusions.

A compendium of examples of measures of effectiveness (MOE) is provided that illustrates the methodology. While this compilation of over two hundred detailed MOE descriptions is specifically <u>not</u> intended as an "approved" list of MOE, nevertheless the compendium does present a comprehensive set of previously used evaluation criteria for combat systems and, as such, is an appropriate point of departure for anyone faced with a new study of the varied aspects of land combat systems. Application of any MOE contained in this compendium must always be made with critical attention to the objectives of the combat developments study at hand. The development of new MOE, as needed, to more completely describe combat systems is always to be encouraged and presents a continuing challenge to the military analyst.

The purpose of this pamphlet will have been served if it helps the combat developments study officer to understand the crucial roles played by measures of effectiveness and if it provides tangible assistance in making the evaluation of combat systems an objective, explicit and considered process. Suggestions for improvement in the pamphlet and newly developed measures of effectiveness are continually solicited and should be directed to the Commander, US Army Training & Doctrine Command, ATTN: DCS-CD, Fort Monroe, Virginia 23351.

TABLE OF CONTENTS

ANNEXES

FIGURES

HEADQUARTERS
UNITED STATES ARMY COMBAT DEVELOPMENTS COMMAND
FORT BELVOIR, VIRGINIA 22060

USACDC PAMPHLET
NUMBER 71-1

31 January 1973

Force Development

THE MEASUREMENT OF EFFECTIVENESS

CHAPTER 1 INTRODUCTION

1. Purpose. This Measurement of Effectiveness Pamphlet responds to the requirement recognized in the Commanding General's Letter (CGL) 1-72, 22 February 1972 (Figure 1-1). This letter is reproduced here because it represents one of the few instances in which major decision making levels have recognized the importance of measures of effectiveness to the Army decision process. This pamphlet provides guidance to combat developments study officers and assistance to operations analysts in the selection and use of valid measures of effectiveness (MOE) in the analysis of Army combat systems.

2. Frame of Reference. CGL 1-72 sets the specifications for the tone and content of the Measurement of Effectiveness Pamphlet. The Pamphlet is to be read and understood as expressing minimum requirements for selecting and applying MOE in the combat developments process. The technical content is based on the fundamentals of algebra and physics, but explicit mathematical considerations are contained in annexes which can be pursued as the occasion of interest arises.

3. Definition. A formal definition of measure of effectiveness, as the term is used throughout this Pamphlet, is: A criterion expressing the extent to which a combat system performs a task assigned to that system under a specified set of conditions. Thus, an individual MOE supplies a partial answer to the question: How well does System X perform assigned Task Y under a set of combat conditions Z?

4. Scope. The scope of the Measurement of Effectiveness Pamphlet covers the development, formulation, and use of MOE in the combat developments process. The roles of measures of effectiveness in analysis, test and experimentation, decision, and documentation are discussed in detail. Emphasis is placed upon the methodology to develop measures of effectiveness which can be best described as an art trying to become a science.

Included is an extensive compendium of examples of MOE that illustrate the methodology. For the most part, the Pamphlet describes the present state of the art; however, at appropriate points in the discussion, suggestions are made for advancing the state of the art.

5. Perspective. The approach of the Measurement of Effectiveness Pamphlet is to describe the "place" of measurement of effectiveness in the combat developments process. The Pamphlet emphasizes that military judgement is as important as scientific judgement in the process of measuring the effectiveness of combat systems. Practical criteria as well as academic and mathematical criteria are considered as the basis for selection of MOE to compare systems. A compendium of MOE is provided that will furnish: (1) Examples that have been used in the past and have potential use, with judgement, for future studies; (2) Examples that have potential for use in elements of doctrine, organization, concepts, forces, and materiel studies; (3) Examples that have potential for use in elements of threat, tactics, technology, techniques, troop organization studies, tests, and experimentation; (4) Examples that have potential for use in elements of command and control intelligence, communications studies, tests, and experimentation; and (5) Examples that have potential for use in logistical studies, tests, and experimentation. These examples have been extracted from virtually all Army combat developments studies and tests since 1965.

6. Organization. In Chapter 2, the place of measures of effectiveness is discussed vis-a-vis the combat developments processes. Chapter 3 provides systematic methodology for the development and application of measures of effectiveness. Chapter 4 provides a compendium of examples of measures of effectiveness. Annexes are provided for bibliography and references, an index of terms, and selected backup academic and mathematical explanations for the methodology.

C O P Y

DEPARTMENT OF THE ARMY
HEADQUARTERS
UNITED STATES ARMY COMBAT DEVELOPMENTS COMMAND
FORT BELVOIR, VIRGINIA 22060

CDCCG 22 February 1972

COMMANDING GENERAL'S LETTER (CGL) 1-72

SUBJECT: Considerations Concerning the Use of Models and Simulations to Assess Systems Effectiveness

TO: Colonel H. J. Childress, Jr.
Commanding Officer
US Army Combat Developments Command
Systems Analysis Group
Fort Belvoir, Virginia 22060

1. The value of analytical means and methods to help solve combat development problems continues to grow in importance. Current utilization of and dependence on such analyses have now reached the point where everyone in the decision-making process must have a common understanding of the capabilities and limitations of analytical technology. I have summarized below my current thinking on this vital area for the guidance of combat developments personnel.

2. Central to the problem of evaluating alternative combat systems — including their doctrinal, organizational and materiel elements — is the requirement for valid Measures of Effectiveness (MOE) which can be applied to assess the effectiveness of various systems across the board, ranging from individual items of materiel through complete force designs such as CONAF, and all the way up to our most complex system studies like LCS-I and ALTSTRAT. There are two equally important considerations in the correct use of MOE:

a. First, prior to constructing (or exercising) a model, simulation, or an experimental design for a field test, we must select those MOE which best describe overall systems effectiveness.

b. Second, our selected MOE must be made acceptable to the Agency which is going to actually conduct the study or test, as well as to the decision makers and DA and DOD analysts who will review the results. We must select the right MOE, and gain acceptance for the MOE both up and down the chain to insure a clear understanding of our methodology — and its limitations — at the outset. The development of good MOE is so important that the Army

C O P Y

CDCCG 22 February 1972
SUBJECT: Considerations Concerning the Use of Models and Simulations to Assess Systems Effectiveness

should make full use of the expertise available on advisory groups such as the PSAC, ASAP and our new CDAG.*

3. Models and simulations must be put in combat perspective before and during the evaluation process. Often, once a set of MOEs is selected, the analyst focuses narrowly on these measurements and fails to adequately consider the numerous intangible factors which tend to make ground combat more of an art rather than a science. Immeasurables, judgmental factors, and the multiple assumptions in a situation can greatly outweigh the effect of the selected MOEs on real systems effectiveness, and render the analysis invalid. Within CDC, analysts should strive to rate the model — and associated MOEs — in relation to the problem under study and advise decision makers, within a stated level of confidence, on the relative weight which the factors addressed in the model have as a percentage of all factors affecting real-world systems effectiveness.

4. The Army's best protection against an over-reliance on, or misuse of, models and simulations — and also against selecting too few or too simplistic MOEs — is to encourage our best combat leaders (tactical and logistical) to become conversant in ORSA. This will insure that an appropriate blend of the art and science of combat is automatically built-in to our analytical work.

5. Two key MOEs which appear to apply to practically all our systems assessment work are:

a. The strategic deployability of the system under evaluation.

b. The capability of the system to operate in a tactical nuclear warfare environment.

I am seeking better guidance for CDC in these areas.

6. We need to develop a clearer appreciation of CDC's overall quantitative and qualitative requirements for modeling and simulation. These requirements must be specific, relatable to our assigned missions, and capable of being documented and understood by the Department of the Army. (DCSOPS)

*Combat Developments Advisory Group

COPY

CDCCG 22 February 1972

SUBJECT: Considerations Concerning the Use of Models and Simulations to Assess Systems Effectiveness

7. To improve our overall systems assessment posture, the following actions should be considered:

a. Expand our CDC "in-house" and outside ORSA training programs. (DCSMAR)

b. Review our earlier request for help from the ASAP on the development of MOE, and prepare a new initiative — if necessary a letter from CG, CDC, to Dr. Lawrence O'Neill -- to reenergize this work. (SAG)

c. Continue our ongoing SAL action to develop a compendium of MOEs, and adjust SAG's priorities to insure the MOE problem gets the attention it deserves. Brief me on the status of this action, and on the most critical MOEs now in use. (SAG)

d. Review and provide a status report on ongoing actions to strengthen COMSG's analytical capability by:

(1) Reassigning agency level spaces to the COMSG HQ. (DCSMAR)

(2) Increasing the numbers and capabilities of personnel in the Leavenworth SAG field office. (DCSMAR)

(3) Making the SAG field office an organic part of COMSG. (DCG)

(4) Establishing an in-house wargaming facility. (DCSOPS)

(5) Encouraging top Army civilian ORSA analysts to relocate to COMSG. (Scientific Advisor)

e. Brief me on the current status and effectiveness of the STANO Systems Assessment Model. (INCS GP)

8. I expect all key personnel of this command to be thoroughly conversant with the contents of this letter (paragraphs 1-6) and to make personal contributions towards rapidly upgrading CDC's analytical capabilities.

John Norton

JOHN NORTON
Lieutenant General, US Army
Commanding

COPY

CHAPTER 2 THE CONCEPT OF MEASURING EFFECTIVENESS

1. General. Measuring effectiveness is an everyday process for most of us and a part of our rational thinking. It can be a weighing in the mind or a more deliberate use of calculations. It involves rational development and, usually, a decision. Most times, it is rechecked before considered action is taken. Each of us is measuring or being measured in our daily functions on the job. The concept is not new but has been with us since man has been weighing the advantages and disadvantages of his tools and weapons -- as he thought about them conceptually and subsequently produced those deemed most desirable. In this Chapter, by way of motivation, we illustrate the measurement of effectiveness process by using an example that is familiar to most of us -- the buying of an automobile. We will show the situation, how we develop our reasons for measuring certain things, and how we arrive at the kind of measures we use: what kind of car we think we want, why we want it, how much we can afford to pay or want to pay, to obtain it -- in short, why we buy what we buy. This somewhat mundane example is intended to illustrate the process of measuring effectiveness in everyday life and provides an introduction to the subsequent discussion of the critically important place that measurement of effectiveness has throughout the combat development process.

2. An Illustration -- Buying an Automobile. Measures of effectiveness are used whenever a decision is made. Although this pamphlet concerns MOE in the combat developments process, everyone actually uses MOE in one form or another quite commonly in everyday contexts. A decision always involves a choice between alternatives, even if the choice is only between continuing on a present course or not continuing at all. A choice necessarily involves comparing alternatives by examining all factors that differentiate between candidate decisions. Whenever any factor becomes part of a comparison, it must be measured in some way. The measure may be quite precise and require complicated instruments, or it may be a less precise judgemental estimate; but in either case, a measure is necessary for a comparison, and a comparison is necessary for a decision.

a. Let us consider a "typical" example of the application of MOE in a real life, non-military situation. Whenever one considers buying an automobile, the competitive free enterprise process ensures that there is a choice of alternatives. The decisions will be made on the basis of all characteristics of the various automobiles available that make them different from one another in relation to the buyer's objectives. These qualities might include acceleration capability, cost, safety, comfort, appearance, dependability, prestige, buyer's relation to the seller, preference for domestic products, and ease of handling. Which of these ten factors (or others) are important depends upon the buyer's objectives. If the primary mission is commuting to and from work, he may value dependability and economy highly; but if the mission includes much long distance business travel, he may prize safety and comfort more highly. Once his objectives are clear he can determine which qualities are most important in the comparison.

b. Having stated the objectives and ranked the qualities in order of importance to him, he will need to measure the effectiveness of the various prospective automobiles (the "candidate systems") in satisfying these objectives. A particular quality may be measured in several ways. There are at least four forms of measurement: nominal, ordinal, interval, and ratio. Each may be measured at various degrees of precision. Furthermore, there are usually several possible measures of each type available.

c. A woman might consider the color of her automobile important for her objectives concerning appearance. In this case a nominal measure would be appropriate. A nominal measure divides candidates into sets but does not allow addition, subtraction, or other arithmetic handling of values. A classification that develops into values such as yes/no, one/zero, or with/without is a special case of nominal measurement. If her preference were for blue alone, her measure would be simply blue versus non-blue.

d. A construction engineer might determine that an auto's durability under adverse conditions is important to his objectives. An ordinal measure which ranks candidates in respect to each other may be appropriate. A four-wheel drive vehicle is considered more rugged than a standard sedan although it might be difficult to compute how much more so. The sedan in turn is ranked over an inexpensive compact in durability. He continues in this manner until all candidates are ordered in place with respect to one another.

e. In another case a real estate dealer may determine that capacity is the most significant factor for his objectives which include taking the maximum number of prospective buyers to house sites. He might be able to employ an interval measure which not only measures which is better but also how much better. He observes that a full-size car carries five adult sales prospects while a medium-size carries four, and a compact three. Similarly, a young man may count prestige as important to his objectives which include performance-conscious friends. He may measure prestige partly in terms of horsepower on an interval scale in which 385 horsepower is not only better than 350, but also makes clear the interval or superiority in this respect.

f. A housewife might be interested in a general purpose vehicle that takes into account several competing objectives. She might want an economical car to make short shopping trips and at the same time she may want powerful acceleration for access to interstate highways on long vacation trips. She might like the sporty appearance that is esthetically appealing to her friends and simultaneously the dependability to preclude breakdowns away from home. She might desire easy handling for parking in the city but at the same time need a car with capacity to transport a whole den of cub scouts safely. Such trade-off's suggest ratio measures that divide the desirability of positive features by the undesirability of negative features. The number of miles traveled is divided by the number of gallons of fuel used, for the ratio of mileage. Ratio measures can be used on a higher level to make trade-off's directly. The ratio measure of mileage could be divided by seconds required to accelerate to 65 mph as an indication of trade-off between economy and acceleration.

g. Given ten or so qualities for comparison, four forms of measures, various degrees of precision in measure, and different measures for each quality, a large number of possible measures is taken into consideration. Having compared a new compact with the current family car, and with a convertible that a brother-in-law needs to sell, plus all the other candidates in terms of miles per gallon, it would still be necessary to consider other elements of economy such as acceptance of trade-in, depreciation, initial sales price, taxes and licensing, maintenance, and insurance. Furthermore, each of these factors in economy may require a different preference in importance before the issue of overall economy has been settled. After economy there are matters of safety, comfort, appearances, dependability, and other qualities to consider, each differing in preference or "weighting" concerning objectives. Sometimes one factor overwhelms all others, as for example when prestige is so important a Rolls Royce is selected regardless of any considerations of cost or any other factor. This has the effect of giving one quality nearly full weight in the decision and assigning all other measures nearly zero weight.

h. Figure 2-1 diagrams a possible decision process. In the far left column the MOE for economy and relation to the seller are shown. Each of the measured values is carried forward to the right in respect to its weight in importance to the third column. In the third column are several qualities. The value assigned to each of these qualities is some combination of the primary MOE values and their "weights." The MOE leading to safety, comfort, and so forth are not shown but would be combinations of primary measures and their weights similar to those shown for economy and relation to seller. When each of the eight or more qualities in column three has a value, their values are then carried forward with their weights to the overall effectiveness rating of one candidate automobile. The third and

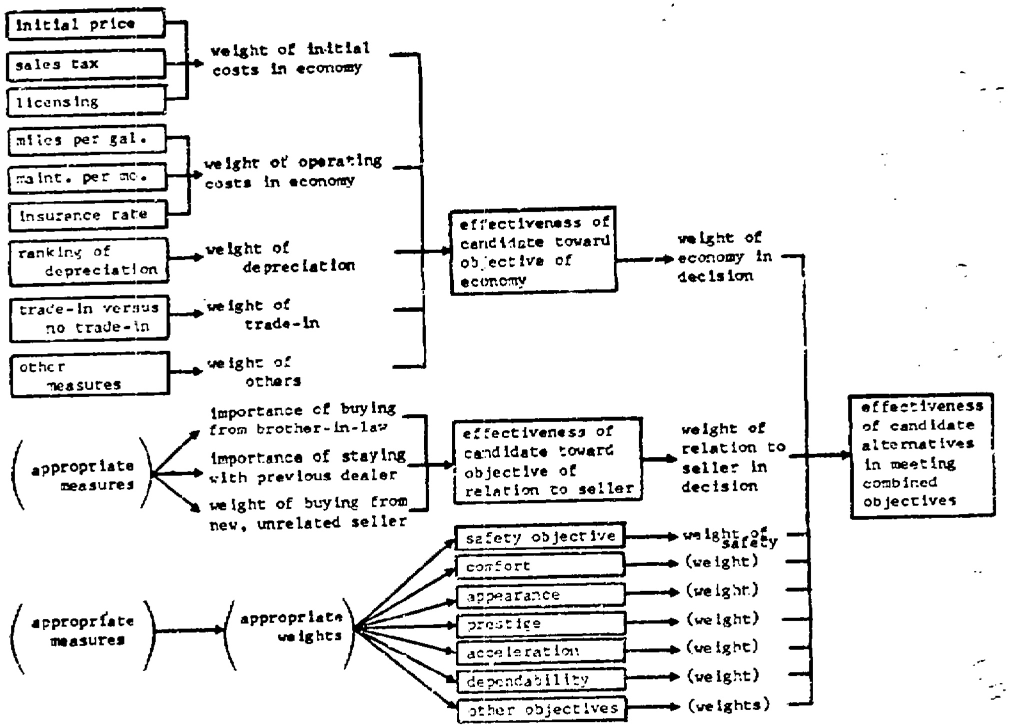


Figure 2-1. Combination of Measures of Effectiveness in Meeting Objectives in Purchase of Automobile

fourth columns were combined to rate a single quality concerning the buyer's objectives. The final combined score in the box in the fifth (far right) column is the measured effectiveness for a single candidate for example, the compact or the brother-in-law's used convertible. The score for each candidate can be compared to the scores of all other candidates in order to arrive at the final decision.

i. This process, or something very much like it, actually is undertaken, whether implicity or explicitly, whenever one makes a decision concerning buying an automobile. In spite of the apparent complexity of the factors in the decision, buying an automobile is a common decision that almost everyone makes from time to time. The final soundness of the decision rests to a significant extent upon the validity of the measures defined and estimated down to the lowest level of the process.

3. <u>MOE and the Combat Developments Process</u>. The example showed the rational process involved in making the decisions to buy the automobile and, subsequently, which automobile to buy. There is a direct analogy between this process and the process used for combat developments. It is important for the study officer to realize that land combat development studies, analyses, tests, and experimentation are performed in order to provide forecasted information about operational concepts, tactical doctrine, equipment, and organizational structures. The information is to be made explicity concerning a set of possible actions to meet a set of desired ends which are evaluated using elements of land combat effectiveness. Because analytical studies are increasingly used as bases for combat developments decisions, they must meet exacting standards and contain specified types and quality of information. Thus, the information provided by these studies needs to be developed and substantiated in a highly credible, quantitative and objective manner. The selection of appropriate measures of effectiveness is central to this credibility, and the MOE used are the most important keys to a successful and approved land combat development action. Selection of appropriate measures of effectiveness is influenced in the earliest phase of the project by the objectives and subobjectives of the study directive and study plan or the test directive and test plan. When models are used, the MOE describe the type of outputs needed, which in turn prescribes the type of inputs needed (not vice versa). In cost-effectiveness analyses the MOE are the predicted consequences of the behavior of considered candidate land combat systems, subsystems, or changes to systems or subsystems. In test and experimentation, the MOE used are essentially the same MOE used in a study of the candidate systems. Figure 2-2 shows that the combat developments process is analogous to the scientific process wherein measurement plays an important role. The phase order in combat developments may not be strictly in the order shown, but the analogy still holds. The following points should indicate why measures of effectiveness are critically important to the success of all phases in combat developments studies.

PHASE	THE COMBAT DEVELOPMENTS PROCESS	PHASE ORDER IN THE PROCESS	THE SCIENTIFIC PROCESS
1.	Study Directive, Study Plan.		Formulating the Problem.
2.	War Gaming, Modeling.		Constructing a model to represent the system under study.
3.	Cost-Effectiveness Analysis.		Deriving a solution from the model.
4.	Test & Experimentation.		Testing the model and the solution.
5.	Materiel Needs and Personnel Needs Documentation.		Putting the solution to work: Implementation.

FIGURE 2-2. ANALOGY OF THE COMBAT DEVELOPMENTS PROCESS WITH THE SCIENTIFIC PROCESS

a. Study Directive. In the study directive the MOE are the starting points for an effective study orientation by the study director. It is part of the formulation and definition of the problem.

b. Study Plan. Here the MOE are refined and expanded thus determining the depth and detail of the study. If it is determined that the sub-objectives are not quantifiable or pragmatically not measurable, then the problem has to be restructured until they can be measured.

c. Modeling and War Gaming. After the problem is formulated, the MOE determine the type and detail of modeling to support a study. This is a normal process for rational problem solving. The model represents the system under study using the MOE to define the outputs needed from the model which in turn help to define the inputs required. Figure 2-3 shows basic type of models used in land combat studies.

d. Cost-Effectiveness Analysis. Here the MOE are the vehicles for comparison of alternative candidate systems. Figure 2-4 shows diagrammatically how the MOE fit into the process.

e. Test and Experimentation. In scientific test and experimentation a hypothesis is established which is tested using measures of essential factors to accept or reject the hypothesis. In combat developments the essential factors to be measured are hypothesized during analysis to be proved or disproved by tests, experimentation, or simulation.

f. Materiel and Personnel Needs Documentation. The basic mission for combat developments is to formulate and document concepts, doctrine, materiel requirements, and organization pertinent to the Army in the Field. Included in that responsibility is the design of land combat systems for at least 20 years into the future to facilitate the integration of new or improved doctrine, materiel, and organizations. The combat developments process includes studies, simulations, and testing and experimentation in which the final product is recommended doctrinal, organizational and equipment changes for the immediate future and for long range planning programs. The recommendations involve estimates based upon the best available information indicating the impact of such recommendations. Doctrinal recommendations are applied in field manuals. Organizational recommendations are applied in Tables of Organization. Materiel recommendations are applied in Tables of Equipment and in materiel specifications. As such the credibility of MOE establishes the validity of such things as basis of issue of equipment, the establishment and maintaining of MOE, and the credibility of requirements for organizational and doctrinal changes.

BASIC TYPE OF MODEL	A GENERAL EXAMPLE	A MILITARY EXAMPLE	A COMBAT DEVELOPMENTS EXAMPLE
ICONIC	MODEL AIRPLANE	SAND TABLE	FIELD TRAINING EXERCISE
ANALOGIC	ROAD MAP SLIDE RULE	SCALE TERRAIN MAP	MAP EXERCISE
SYMBOLIC:			
ANALYTIC			
DETERMINISTIC	OHM's LAW E = IR	MOVE TIME = DISTRANCE/MARCH RATE	BONDER-IUA (BONDER-INDIVIDUAL UNIT ACTION)
PROBABILISTIC	PROBABILITY DISTRIBUTION	CASUALTIES=NUMBER ENGAGED X PR (HIT)	SIMTANK (SIMPLE TANK MODEL)
DISCRETE			
DETERMINISTIC	AIRLINE MILEAGE TABLES	FIREPOWER SCORES	TRANS-HYDRO (LOGISTICS-OVER-THE-SHORE)
PROBABILISTIC	WEATHER PREDICTIONS	PR(0,1,2,...,n) HITS WHEN n ROUNDS ARE FIRED	PR (HIT) TABLES FOR RANGE-AMMO TYPE COMBINATIONS
HYBRID			
DETERMINISTIC			REDLEG (ARTILLERY MODEL)
PROBABILISTIC			DYNTACS (DYNAMIC TACTICAL SIMULATOR)

FIGURE 2-3. MODELS IN USE IN COMBAT DEVELOPMENTS

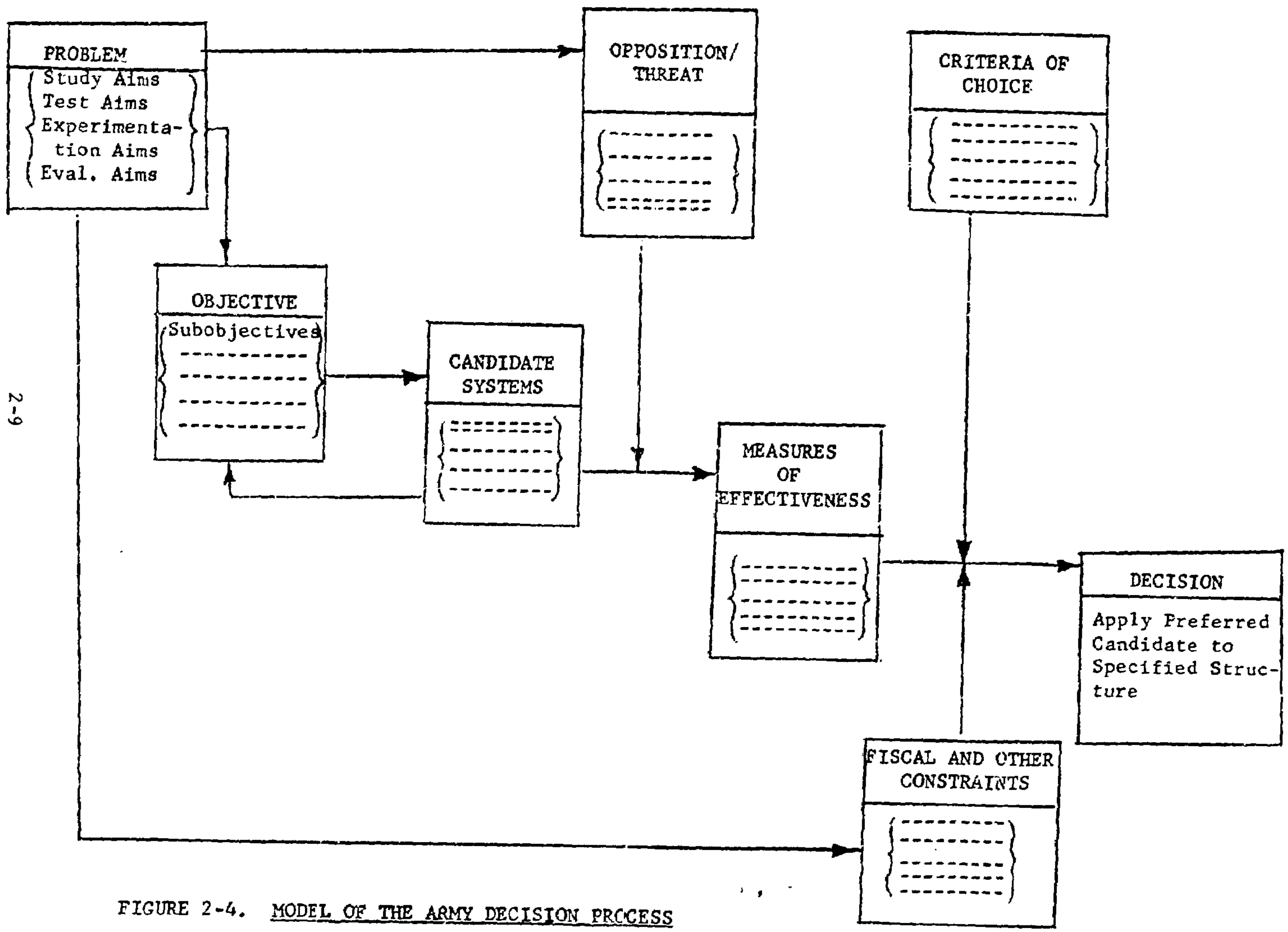


FIGURE 2-4. MODEL OF THE ARMY DECISION PROCESS

g. Decision. The culmination of the combat developments process is the recommendation to higher authority which of the alternative combat systems should be developed and eventually fielded. These decisions are inevitably couched in terms of MOE The role of MOE in the Army decision process is often implicit but nonetheless real. Interjecting scientific objectivity into the decision process involves making explicit the various MOE and their selective weights which are driving the decision. This most important aspect is discussed in Chapter 3. At this point it is sufficient to note that virtually no Army decision concerning the development of a new combat system is ever made without at least an implicit consideration of MOE. Making these considerations as explicit as possible should be a continuing goal of a rational combat developments process.

4. Summary. The concept of measuring effectiveness is really not new to any of us. It is used in our daily functions on the job and in evaluating our personal needs.

a. A typical example is when one considers buying an automobile. Usually there is a choice of alternative candidates. The decision to buy one of them will be based on all characteristics of the various automobiles that are specific to the buyer's objectives. Once the objectives are clear -- e.g., to commute to and from work, for long distance business travel, for prestige, for family pleasure, or for possible combinations of each -- the buyer can then determine which qualities are most important in comparison. The qualities might include cost, safety, comfort, appearance, prestige, relation to the seller, acceleration capability, preference for domestic products, and ease of handling. Once the objectives are clear and the most important qualities are determined, then the buyer sets up a set of rules in his terms for measuring the effectiveness of each of the perspective automobiles.

b. The process is conceptually similar for combat developments but much more complex and formalized. The qualities desired are different and more complex, but the rules for measuring and decision are very nearly the same. ANNEX D covers most of the basics of measurement that a combat developments study officer needs to know for a fundamental understanding of the use of measures of effectiveness.

CHAPTER 3. TECHNIQUES FOR DEVELOPMENT AND APPLICATION OF MEASURES OF EFFECTIVENESS

1. General. An evaluation is a comparison. The system evaluated is compared to other systems, or to the same system under other circumstances. An effectiveness evaluation makes the comparison in terms of effectiveness rather than on the basis of other possible points of comparison, and a combat effectiveness evaluation compares a system's effectiveness under combat conditions. Effectiveness may be expressed as maximizing performance, minimizing cost, or optimizing both at the same time. Whenever possible the comparison is made between numerical descriptions of effectiveness; but whether the indicators of effectiveness are numerical or verbal, they are called measures of effectiveness. It is sometimes difficult to measure effectiveness because of complex or subtle relationships among factors, as discussed in ANNEX D; but unless effectiveness is measured, there can be no actual objective evaluation. It is always desirable and usually necessary to state the relationship of relevant factors contributing to effectiveness. This can be done by constructing a representation of the logical framework of functional interdependencies among the elements of a system and its environment. This logical framework, or model, may be as simple as a verbal rule of thumb or a single formula, or as complex as a set of interrelated equations in a computerized simulation. A model makes it possible to exploit the powerful tools of analysis and experimentation to predict results of changes in the system. When the relevant factors are immeasurable, or only some of them are measurable, estimates are used and the evaluation cannot be wholly routine and mechanical. This is usually the case in complex military systems, so that both military judgement and analytic techniques are required in most combat developments projects. Just how much of an evaluation is judgemental and how much is analytic determines the appropriateness of possible measures of effectiveness. Appropriateness is discussed in ANNEX D, but in summary an appropriate MOE has five elements: (1) it addresses an objective of the system; (2) it is reliable in the sense that it yields the same value under the same circumstances; (3) it is valid in the sense that it correctly predicts results; (4) it is at the correct level to assess effectiveness of a system in a given situation; and (5) it is as quantitative as possible.

2. Approach to the Development of MOE. MOE have to be acceptable to Army decision makers and fit their needs. In order to reliably forecast the consequences of future actions, it is necessary to develop quantitative relationships of a hypothetical (if/then) character. It is here that the methods of operations research are applicable. These methods alone, however, do not make MOE acceptable. Prcatical judgemental considerations have also to be a part of the MOE process.

a. Criteria for MOE. (Figure 3-1) Measures of effectiveness have to be developed for each new study and test because no one set of MOE has been forwarded that fits all situations. The criteria for MOE that evaluate proposed land combat systems in keeping with specific study purposes are discussed in Chapter 2. There are three criteria for selecting final MOE from a list of considered measures.

(1) The first criterion is that an MOE express the extent to which a system meets the best possible performance. An MOE may express system performance as a proportion of maximum performance. Percentages and probabilities are direct measures of effectiveness because percent is proportion of the best value, 100%, and probability is proportion of highest probability, 1.00. Other measures can be made into MOE by expressing them as the ratio of actual and best results. For example, percent of targets hit and probability of hit are MOE, and firing rate is a measure of performance that can be converted into an MOE by dividing it by maximum required (or desired) firing rate. Ton-miles per hour is a measure of performance that can be converted into an MOE by making it a proportion of required ton-miles per hour. Obviously, making the best required performance the denominator of the measure means that MOE can only be developed in keeping with the objectives of a system.

(2) The second criterion for MOE is that they should be consistent in quantities and units as discussed in ANNEX D. This criterion requires that the analyst consider how the numbers expressing the MOE are to be manipulated mathematically in order to derive conclusions concerning the effectiveness of the systems being evaluated.

(3) The third criterion is that the MOE be "appropriate" in accordance with the definition given in Figure 3-1, and explained and demonstrated in this Chapter. This criterion requires that the analyst insure that the MOE chosen produce results which incorporate in a consistent way the objectives of the systems evaluated.

b. Creative Thinking to Develop MOE. A major problem to most analysts is their apprehension in selecting MOE that could contribute to errors in the conclusions of a study. This causes the analyst to be too critical to start with. As a result, many potentially good MOE are dropped out too early in the selection process. It should be understood at the beginning of a study, test, or experiment that there are no completely comprehensive lists of MOE available. Chapter 4 contains a compedium of MOE, but it consists only of representative illustrations of MOE that have been used or could be used under appropriate circumstances. The way to go in setting up candidate MOE

CRITERIA FOR MOE

POINTS TO CONSIDER	WERE DISCUSSED
1. Criterion of choice should be well defined for the MOE.	Chapter 2
2. Quantities and units of the measure should be consistent.	ANNEX D
3. MOE are appropriate because:	Chapter 3

- The MOE has an objective.
- The MOE is reliable.
- The MOE is valid.
- The MOE is at the correct level of objectives for the situations considered.
- The MOE is accessible to quantitative estimation.

FIGURE 3-1. CONSIDERATIONS FOR THE DEVELOPMENT OF MOE is to drive through the logical maze of what the study appears to be and then "brainstorm" MOE, possibly use some of the MOE contained in the compendium, add others, and even use quick guesses. It pays to be creative first and precise afterwards; in that way a foundation of possible MOE is laid from which a good set of MOE can be selected. It will become apparent after the study is on its way what the criteria of choice among alternative systems will be and, hence, which MOE will then be needed and appropriate.

c. Military Judgement in Developing MOE. Answering questions regarding which MOE to consider and ultimately adopt demands a background of experience, especially military experience. The experience we are referring to reaches back into many generations of practitioners of the military and analytical sciences. If, for instance, we are to treat a certain problem using only a "firepower" measure of effectiveness (for example, by resorting to a formulation depending upon "ballistic effects" and "rate of fire"), we must have enough background to be assured that "mobility of the weapon system" is not an essential item under the specific circumstances of the problem. Thus, experience has to indicate the laws which govern the variation of the systems, and which of the elements that must be considered in formulating the relations between the parts. It is thus that systematic errors in the formulation are kept to a minimum. (A discussion of "systematic error" in the use of MOE is contained in ANNEX D.) Furthermore, military judgement necessarily has an impact upon the development and assessment of MOE. The points of impact occur throughout the land combat study and test and experimentation process from the definition of the problem through to the conclusions, recommendations, and implementation where required. The reasons for the need of military judgement are mostly based on the need for credibility in the measures used and the results obtained with those measures. Figure 3-2 shows some of the reasons.

d. MOE Derived from MOE Objectives. The purpose of a specific measurement of effectiveness is to be derived by means of a statement of objectives. This statement may not necessarily be the same as the statement of the purpose of the study. It is usually derived from the sub-objectives and essential elements of analysis in the study. The process involves a selection of a set of best criteria in order to compare candidate systems usually having variations of certain desirable characteristics. Once these criteria are determined, then the measurements have to be bounded by the six considerations shown in Figure 3-3.

MILITARY JUDGEMENT IS NEEDED BECAUSE

1.	Error in Evaluating MOE	Statistical inferences in land combat operational effectiveness cannot always be reliable.
2.	Comprehensiveness of MOE	Evaluation of the real merits of alternative candidate systems is not accomplished mechanically.
3.	Unequal Importance of MOE Chosen	Rational choice between candidate systems goes beyond measure and scale. It has to involve a sense of worth or importance, therefore, an additional dimension of value.
4.	Non-Quantified MOE	Proper weighting of such attributes as "leadership", "flexibility", "convenience", and "morale".

FIGURE 3-2. THE NEED FOR MILITARY JUDGEMENT IN DEVELOPING CREDIBLE MOE

1. What is to be compared?

2. What are the differences upon which the comparison is to be made?

3. What are the circumstances (of combat) under which the comparison is to be made?

4. What is the maximum possible amount of each difference?

5. What vehicle (test, model, judgemental analysis) will be used to determine the impact of differences upon effectiveness?

6. What methods will be used to present the possible errors associated with the measuring process?

FIGURE 3-3. CONSIDERATIONS IN DERIVING MOE FROM SYSTEM OBJECTIVES.

An example such as the following describes the process of developing an MOE from a sub-objective.

EXAMPLE: (1) Sub-objective:

"To compare alternative Field Army level communication systems having different mixes of satellites by comparing their traffic handling capability and vulnerability with existing systems in the European Theatre of Operations during the 1975-1980 time frame."

(2) MOE Objectives:

"Traffic handling capability"

"Vulnerability"

(3) MOE Definition could be:

"Traffic handling capability is measured by the percentage of calls completed to those requested."

"Vulnerability is measured by the probability of completing a call while the candidate systems are subjected to electronic countermeasure."

Because the goal of a land combat study or test is usually to compare candidate systems at some organized level, principal differences are to be considered in order to distinguish the candidate systems one from another. The qualitative characteristics bound the scope of the investigation and stipulate the nature and number of MOE to apply. (In the example there are two: "Traffic handling capability." and "Vulnerability.") The general environment and time frame sets the conditions under which the candidate system is to be compared. (In the example they are: European Theatre of Operations and 1975-1980 time frame.) The criterion of choice defines what the candidate systems are to be compared to: whether specified performance, a specified candidate system, or some baseline system.

e. Evaluating Alternative MOE. After "free-wheeling" for as many MOE as one can think of, the study officer may note that there are similarities among them. The next step is to evaluate and, possibly, reduce the number of alternative MOE. Figure 3-4 illustrates a suggested procedure to accomplish this. Each remaining MOE should then be evaluated for mathematical consistency with the proposed analysis procedures and for consistency with the objectives of the systems to be evaluated.

ACTION	REASON
1. Eliminate Alternative MOE	a. Technical Infeasibility. b. Economic Infeasibility. c. Clearly Dominated by Other Alternatives.
2. Consider Eliminating Other MOE	a. Weak at the Most Important and/or Most Frequent MOE Objective. b. Has Greater Risk Relative to Other Alternative MOE.
3. Rank Remaining Alternative MOE	a. Differences in Sensitivity to Unknowables. b. Differences in Robustness Against Counteraction. c. Differences in Preservation of Flexible Options. d. Differences in Contribution to Longer Term Goals.
4. Reexamine Those Eliminated	a. They May Be Better Than First Realized. b. What is Left May Make Another Alternative More Appealing.

FIGURE 3-4. A METHOD TO APPRAISE ALTERNATIVE MOE

f. Point towards the Next Higher Level.

(1) Part of the criterion of selecting MOE consistent with the objectives of any given study is to pick MOE appropriate to the operative decision-making level. There is a hierarchy of MOE which is analogous to the levels of decision being addressed. As a general rule, a measure of effectiveness at one level (say, the combat developments level) is dependent upon one or more measures at the next lower level (say, the system performance level). For example, the ratio of red losses to blue losses (a typical combat developments level MOE) depends partially upon the rate of fire (a typical system performance level MOE). The key point here is that a system's effectiveness in its own domain (or level) is not usually as important as its contribution to the next higher level. Care should be taken to select the MOE at the correct level in the "MOE hierarchy." This, in itself, will help to insure that the MOE are applied at the correct level of objectives. (The MOE hierarchy is discussed in detail in ANNEX C).

(2) An example of these hierarchical considerations is selection of MOE for a particular type of night vision device. One measure of performance for such a device could be the number of targets it detects; a corresponding MOE would be percent detections of targets presented to the device. This is a good MOE but limited in usefulness to the next lower level, namely evaluation of components of the device to increase probability of detection. A more interesting evaluation of this type of device would be one based on the next higher level. In this case the next higher level is the tactical unit that combines the devices, their operators, and techniques of employment. At this next higher level a measure of performance is the number of detections by the whole unit including those by other means than the night vision devices, and the MOE is percent of the unit's targets detected by night vision devices. This expresses the device's performance in terms of its contribution to unit effectiveness, which is a more useful measure than the device's performance in its own domain. This would be apparent if two devices were compared and each detected 90% of the targets presented to it but one detected 75% of targets presented to the unit while the other detected only 50% of unit targets.

3. Application of the MOE.

a. Mathematical Notation of MOE. When knowledge of the implications of one or more of the available MOE for evaluating candidate systems is incomplete or nonexistent, the usual procedure for obtaining information is to perform an analysis or a series of experiments. The analysis could be computerized or it could be wholly a paper exercise. Experiments can include field tests, field experiments, computer simulations -- each based

CANDIDATE SYSTEMS	MEASUREMENT OBJECTIVES	ASSOCIATIVE MEASURES OF PERFORMANCE				ASSOCIATIVE OR ALTERNATIVE MEASURES OF EFFECTIVENESS			
		MOP_1 *	MOP_2	. . .	MOP_n	MOE_1	MOE_2	. . .	MOE_n
A_1 *	O_a *	* *							
	O_b								
	. . .								
	O_z								
A_2	O_a								
	O_b								
	. . .								
	O_z								
. . .	O_a								
	O_b								
	. . .								
	O_z								
A_n	O_a								
	O_b								
	. . .								
	O_z								

* The ajectival or formula descriptors.
** Numerical values.

FIGURE 3-5. <u>WORKSHEET FOR TABULATED MOE</u>

RED THREAT ⇩ | BLUE CAPABILITY ⇩ | ENVIRONMENT ⇩

	INTEL/ACO	MANEUVER	FIREPOWER	CMD & CONTROL	SUPPORT
Weighted MOE for A Functional Area (How the Candidate System Performs.)	$W_{11}\ A_1$ $W_{12}\ A_2$ ⋮	$W_{21}\ M_1$ $W_{22}\ M_2$ ⋮	$W_{31}\ F_1$ $W_{32}\ F_2$ ⋮	$W_{41}\ C_1$ $W_{42}\ C_2$ ⋮	$W_{51}\ S_1$ $W_{52}\ S_2$ ⋮

$$W_{11}A_1 \oplus W_{12}A_2 \oplus \ldots W_{21}M_1 \oplus W_{22}M_2 \oplus \ldots W_{31}F_1 \oplus W_{32}F_2 \oplus \ldots W_{41}C_1 \oplus W_{42}C_2 \oplus \ldots W_{51}S_1 \oplus W_{52}S_2 \oplus \ldots$$

Combat Effectiveness of a Candidate System $\quad E = \mu_1 A \oplus \mu_2 M \oplus \mu_3 F \oplus \mu_4 C \oplus \mu_5 S$

DECISION $\quad D = E \oplus$ JUDGEMENT OF THE IMPACT OF "UNMEASURABLE" FACTORS

TERMINOLOGY

W_{ij} = Military judgement weight for the importance of MOE_i in Functional $Area_j$.

A_r, M_e, F_m, C_n, S_p = Sets of MOE in various Functional Areas (Expressed as Blue/Red ratios).

μ_j = The Decision Maker's weights of importance for Functional Area.

FIGURE 3-6. FRAMEWORK OF A COMBAT SITUATION WITH APPLICATION OF MOE on some experimental design for statistical analysis.* In all cases, the quality of the input information used to calculate an MOE is a function of the design of the experiment or analysis and the validity of the associated raw data. In the measurement of effectiveness process, the raw data obtained from an analysis or experiment is generally of little value by itself. It must be processed, i.e., converted to information. A vehicle used to convert raw data to information is called a measure of effectiveness. In order to do this one tries to formulate an arrangement of the data or develop an algorithm by which one can rank the candidate systems. Figures 3-5 and 3-6 are examples of ways that this can be done; each of these Figures is discussed below. Sufficient mathematical machinery now exists to define the concept of measure of effectiveness and explore it in detail. Some of this is given or referenced in ANNEX C and some in ANNEX D. Although it is definitely needed from a professional operations research point of view, the full and abstract formulation of a mathematical theory of measures of effectiveness and the development of the mathematical notation lies outside the scope and purposes of this pamphlet. If further investigation is desired, the preliminary notes in ANNEXES C and D and the references in ANNEX A may be consulted.

b. Tabular Spread Sheet. At times the MOE may be unmeasurable in practice or involve combinations of numbers of different character (i.e., mixed scales: rank, interval and ratio.) Furthermore, it might occur that the critical matter of "importance" of a measure does not easily lend itself to simple numerical treatment. When such a situation develops there is a temptation to develop some simple weighting type approach and a Grand Score calculation routine. Instead of this approach, however, it is better first to explicitly depict the facts as perceived in some sort of tabular spread sheet format. An example of such a spread sheet is shown as Figure 3-5. When this procedure is followed, a judgemental evaluation or dominance analysis can be made of the most preferred candidate systems. (ANNEX E contains a rigorous mathematical treatment and explanation of such matrixing of MOE for candidate system evaluation.)

c. Modeling the Combat Situation. Another useful technique is to analyse the combat situation. Figure 3-6 presents a possible framework using five functions of combat. The scenario and threat are portrayed and each of the MOE within a functional area is weighted (W_{ij}). In addition, the function itself is weighted (U_j) in order to evaluate the candidate system's overall combat effectiveness when all functions are considered. (This structure is evaluated for each alternative system under study.) The symbol $\oplus$ indicates that the formulation consists of some mathematical operation,

*C.B. Bates, "The Role of Design in Experimental Investigation." Technical Reports, ANNEX A.

perhaps not just simple addition.* Although this structuring in terms of five functions is somewhat arbitrary and does not fit all cases, some such structure certainly underlies consideration of alternative candidate systems during the combat development decision process. When this structure, and evaluation tools such as simulation and field experiments to generate quantitative MOE values are used, such questions as the following clearly need to be addressed:

(1) DOES THE MODEL OR TEST ADEQUATELY MEASURE THE INDIVIDUAL MOE? (Can be answered by examining assumptions underlying the model's use and the accuracy of the model input data. For tests, the adequacy of the experimental design would be evaluated.)

(2) WHAT MOE ARE NOT ADDRESSED BY THE MODEL OR TEST? (A measure of this deficiency might be given by the sum of w_{ij} which the model does not address.)

(3) WHAT IS THE ESTIMATED IMPACT OF UNMEASUREABLE FACTORS? (One way is to reduce the decision maker's judgement factor assigned to a Functional Area j containing unmeasurable factors. This adjustment will result in a lower E for the candidate system.)

4. Statistical Testing. Values resulting from measures of effectiveness are tested in order to determine the degree of risk that may be present in the information processed from the data. As discussed briefly in ANNEX D, there are many statistical tests that may be applicable. Such testing should always be considered and, where possible, actually performed in order that the decision-maker can be made aware of possible uncertainties in the MOE values predicted by the study analysis.

5. Summary. MOE have to be not only analytically precise but logical and intuitively acceptable. They must lead to practical and explicit representations of the effects being portrayed for the candidate systems under study. MOE are created for specific circumstances and must be backed up by military judgement. A suggested procedure for the development and application of MOE is the following:

a. Development:

(1) Initially develop as many MOE as possible from the study or test subobjectives.

* In order to bound the effectiveness measure and avoid combining unlike quantities, each MOE could be "normalized" to the most favorable MOE value for the alternative systems under study. This process is illustrated by a hypothetical example given in ANNEX E. Further research with this approach is continuing.

(2) Create as many more MOE as possible, brainstorm even though at first many of them may appear to be alike.

(3) When it appears that all possible MOE have been advanced, categorize them into groups of similar measures.

(4) Appraise the alternative MOE in each group using a selective procedure to evaluate those that are strong or weak, or alike or similar. Figure 3-4 is a suggested method to do this.

(5) Point the remaining MOE to the next higher level of objectives: i.e., insure that the MOE are so constructed that they can serve as performance indicators to the next higher level. If not reconstruct them so that they can.

(6) Express the MOE in standard notation of physics, engineering, and mathematics.

b. Application:

(1) Apply the MOE in a methodical manner (using appropriate test instruments such as simulation, field test, judgemental analysis) to measure, portray, and evaluate effectiveness. Two examples are as follows:

(a) A tabular spread sheet (Figure 3-5) will make it easier to use judgemental factors and dominance to arrive at the most preferred candidate systems.

(b) Structuring the situation in some manner (Figure 3-6) will be most useful in functionally grouping MOE into single composite measures of effectiveness.

(c) Statistically test the MOE values for type/degree and range of risk in the measurements.

CHAPTER 4. A COMPENDIUM OF MEASURES OF EFFECTIVENESS

1. Introduction.

a. Purpose of the Compendium. Potential MOE are listed to aid the study officer in developing his own MOE for a current action.

b. Use of the Compendium. The list of potential MOE is intended to suggest ideas for development of MOE; it is not intended as a list of approved MOE. The study officer and analyst are not encouraged to uncritically select described MOE for use. Rather, they are encouraged to review the listed MOE for ideas toward developing the unique MOE they will need for their specific action. Almost all measures used in Army combat development actions since 1965 are listed. The MOE included vary widely in quality, and even when the analyst finds an applicable measure, he may well be able to improve on it in developing MOE for the action at hand. The appropriate use of the compendium is to provide ideas for candidate MOE.

c. Organization of the Compendium. Since no general theory of measurement is advanced, the compendium organizes MOE in a manner convenient to analyst review for leads. The categorization is by subject matter. The first part is organized into five functions of combat developments: doctrine, organization, materiel, training, and logistics. The second part is organized into five functions of land combat: command-control-communications, firepower, mobility, acquisition-intelligence, and combat service support. Previously used measures and potential proposed MOE are divided into these ten categories to assist the action officer in reviewing ideas toward development of his own MOE. In cases where an MOE might reasonably have been included in more than one category, it has nevertheless been placed into a single category to avoid unnecessary redundancy. This means the action officer must usually review more than one category. For example, an action concerning organization of an intelligence unit will probably find relevant leads in the categories of organization, materiel, and intelligence. There may also be suggestions in other categories, such as doctrine or command-control-communications. In addition to the MOE suggested by the compendium in a given area, it will be necessary to construct some original measures in keeping with the objectives of the action. After this list of candidate MOE has been used in initial attempts at the model or test design, the compendium may be useful again in providing ideas for revising the set of MOE to be used. The compendium is arranged for convenience into ten categories of subject matter. Within each category there is no scheme or ordering other than an intent to group similar subtopics.

2. Presentation of each MOE.

Each MOE in the compendium is titled at the top of a page in capital letters. The MOE title is the simplest possible phrasing of the measure, so that the title is a convenient rather than a complete statement of the measure. The complete statement and description of each MOE is presented in seven paragraphs.

a. Definition of the Measure. The first paragraph starts with the complete statement of the measure. The paragraph includes the input data, the output number, and the relationship between input and output. In each case all the elements of input are stated and the method of processing the input to obtain the single output number is shown. In most cases the method of processing is shown in the form of a computational formula or other notational means for expressing the output as a function of input. The anlayst should keep in mind that the definition is meant to be precise and unambiguous only for the particular described measure, but that he is not constrained by the computation procedure if he desires to use essentially the same measure modified for his own specific objectives. For example, a previously used MOE may be a percentage and include in its definition the multiplying of a decimal fraction by 100% to convert it to a percentage. The action officer may find it more relevant to use the measure in its decimal form or even in its fractional form. The fractional form would usually be a better MOE in the case of very small numerators and denominators in the sense that 1/2 or 7/8 may be more meaningful than 50% or 87.5% when the results are actually one out of two or seven out of eight. In respect to changing the form of measure, however, it should be pointed out that some measures have become fairly standard Army studies and tests; and their definitions are generally accepted, e.g., circular error probability, loss exchange ratio, operational readiness, probability of detection, and mean time between failures. When the action officer changes the form of computation for a measure for his own particular project, he should change the name of the measure too, to avoid confusion with the same name in other actions.

b. Dimension of the Measure. The second paragraph states the form of the measure and the unit of measure for the output number. The form may be a sum, difference, rank ordering, product, quotient, or some more complex form. A sum may be a simple number count or addition of number counts. A difference may be a subtraction of number counts, or subtraction of two values such as start time and end time. Quotients include proportions, ratios, and percentages. In some cases a complex form may result in an index number that has no simply stated form other then the definition of the measure. The dimension of the measure includes the unit of measure of the output number. For example, the unit of measure for "percent casualties" is each casualty and the unit of measure for "rate of movement" may be kilometers per hour. In some cases, especially index numbers, there is no output unit of measure that can be stated less simply than defining the measure, so that the unit of measure is a pure number. The analyst may note that the form of the measure is one of the areas of greatest flexibility in developing MOE. Almost any measure can be changed in form for a particular purpose. For example, a measure of casualties inflicted may be suggested in the form of a sum, a simple number count of casualties or a sum of number counts by different means. The form could be changed to a difference between the number of Red personnel at the start of the engagement and the number at some point in time, if attrition is at issue. It could be converted to a product if that fits the purposes of the action, for example the potential casualty total obtained by multiplying the casualties per type weapon by the numbers of that weapon committed. It could be a ratio of number of casualties over number of personnel at the start of the engagement. Or it could be a more complex form such as the slope of the curve of cumulative casualties over time. The analyst may be interested in essentially the same measure as that suggested by the compendium, but in a different form. Many of the combat service support measures included in the compendium are simple sums such as tons delivered or rounds expended. The action officer may find it more meaningful in some context to convert this to ton-miles delivered, or rate of expenditure of ammunition. Generally, changing to a more complex form gives a more sensitive measure but imposes more limits on the range of the measure.

c. Limits on the Range of the Measure. Many measures have no limit on input or output; all values may vary freely from $-\infty$ to $+\infty$. In many cases, however, the output is limited. For example, a probability is limited to the range .00 to 1.00, number count sums are limited to positive values, and some quotients are defined such that they can not exceed unity. There may be limits to the input values which must be considered by the action officer in developing a measure. For example, most ratio's are meaningless if the input value to the denominator is zero and decimal fractions are limited to the precision of the input. Where there are apparent limits on the range of the measure, the compendium includes them in the presentation of MOE.

d. Rationale for the Measure. The fourth paragraph discusses why the particular MOE described was considered useful when it was proposed. If it is a previously used measure, the paragraph tells why it was selected for the action referenced. If it is a potential or proposed measure that has not previously been used, the rationale explains what properties may make it useful. The rationale given in the compendium might not be applicable to a given action under development, but may furnish the analyst some ideas toward developing his own measure. For example, helicopter air-to-ground detection time was measured in a field experiment because it is one of the components of helicopter survivability against anti-aircraft fire. An analyst may not be interested in air-to-ground detection time but he may agree that some measure of aircraft survivability is important to his action and proceed to develop a more relevant measure. Regardless of how the action officer uses the information in the compendium rationale, he should keep in mind that he must have a rationale to defend the selection of each of his own MOE and that the rationale must take into account the cost of making the measure.

e. Decisional Relevance of the Measure. The fifth paragraph states the circumstances in which the measure would contribute to the decision process. It extends the discussion of usefulness started in the rationale paragraph. While the rationale stated why the MOE would be useful in general, this paragraph goes on the explain when and how the output value can be used in the decision process of a combat development action. A measure may be useful in some other context but not applicable to the action at hand. For example, an MOE that has been used in several tests of intelligence systems is "percentage of targets detected", but was applied inappropriately in a doctrinal troop test. The troop test found that both the standard and the experimental doctrine resulted in 50% detection of enemy targets, while in the standard doctrine a very low percentage of friendly targets were detected. If the friendly intelligence system had been the issue, the MOE would have been appropriate and would have led to the decision that there was no difference between the two candidate doctrines. The appropriate measure might have been the relative friendly to enemy detection ratio, leading to a meaningful decision concerning targeting opportunities. In considering decisional relevance, a single MOE is seldom able to stand alone. In most cases associated MOE must be taken into account.

f. Associated MOE. The sixth paragraph lists associated measures found elsewhere in the compendium. The associated MOE are other measures which would probably have to be used in conjunction with the MOE described. Since the associated MOE are completely presented elsewhere, the form of association is not stated; only the titles are given to make it possible to refer to the other descriptions.

g. References. The final paragraph in the MOE description names actions in which the measure was used if it has been used since 1965. Actions include studies, field experiments, field evaluations, and field tests. Many of the MOE included in the compendium have been used in only one previous action. Some of the MOE included are potential proposed measures that have not previously been used and have no references. This paragraph lists only the USACDC action control number (ACN) and designation of the previous action. The reference can be traced through the bibliography if further information is required.

3. Contents of Compendium. The compendium contains 207 MOE divided into ten categories of subject matter. The categories, number of MOE in each category, and page number of the start of the category are listed first. In the section for each of the ten categories, there is a sub-index listing all MOE in the section and the page number where that MOE can be found. For ease of overall reference, these sub-index listings are reproduced in ANNEX F.

DOCTRINE

PROBABILITY OF SUCCESS

1. DEFINITION OF THE MEASURE: Probability of success is a general term for any of a group of indicators based on the incidence of success in accomplishing a stated objective as a proportion of the opportunities for successful accomplishment. Input data are the number count of observed successes and the number count of potential opportunities for success. Relation of output to input is:

$$\textbf{probability of success} = \frac{\text{number of observed successes}}{\text{number of opportunities (or attempts)}}$$

Alternatively, the data may be in the form of probabilities for various types of failure (PF1...PFn) such that probability of success would be:

$$P_S = 1 - \left[(PF_1)\ (PF_2)\ldots(PF_n)\right]$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a probability.

3. LIMITS ON THE RANGE OF THE MEASURE: Probability may vary from zero to unity, inclusive. Its main disadvantage is that it usually subsumes a set of factors which must also be treated separately.

4. RATIONALE FOR THE MEASURE: This is a direct measure of mission accomplishment and is directly useful in a predictive sense.

5. DECISIONAL RELEVANCE OF THE MEASURE: Probability of success can be used to compare alternative systems in effectiveness in several subject areas. Number of successes may be engagements won, objectives seized, missile flights completed, fire missions on target, aircraft flights surviving, targets destroyed or neutralized, moves completed in accordance with plan, orders executed as intended, or any indication of favorable outcomes in relation to all outcomes.

6. ASSOCIATED MEASURES:

Percent tasks completed	Reliability
Probability of detection	Probability of survival

7. REFERENCES:

ACN 15758, ASARS I, Jun 70
ACN 07346, Optimum Mix of Arty Units 1971-75
ACN 15724, Optimum Mix of Arty Units 1975-80
ACN 13138, Divisional Arty Study
ACN 13708, TACFIRE Cost Effectiveness Study
ACN 06488, Artillery Study 1970-75
ACN 03434, LANCE Cost Effectiveness Study
ACN 15137, Support of Airmobile Operations
ACN 03010, Infantry Rifle Unit Study - 75
ACN 07395, Ground Observer Field Experiment 31.1, Sep 68
No ACN - System Effectiveness Status Report (PERSHING), Feb 72
No ACN - "Candidate Measures of Effectiveness for Air Strike Systems," Naval Weapons Center Report #TP4687, Sep 69
No ACN - Proceedings of the Third NMC Systems Performance Effectiveness Conference, 1967

FORCE EFFECTIVENESS INDICATOR

1. DEFINITION OF THE MEASURE: Force effectiveness indicator (FEI) is the ratio of the total value of the blue force (TVB) and total value of the red force (TVR):

$$FEI = \frac{TVB}{TVR}$$

The total force value for blue (TVB) is computed as the sum (Σ) of the number of each type red weapon destroyed (n_i) multiplied by the value of that type weapon (v_i) for all red weapons (k), and the total red force value is computed similarly for all blue weapons (1):

$$TVB = \sum^{k} n_i v_j \qquad TVR = \sum^{1} n_j v_i$$

The unique characteristic of this measure is that weapon values are computed as the fractional value of the enemy force destroyed by a given weapon. That is, the value (v_i) of a type blue weapon (i) is the ratio of all (1) the numbers of red kills by that type weapon (n_{ij}) multiplied by the values of the destroyed red weapons (v_j) to the total red value (TVR), and the value of blue weapons is computed similarly:

$$v_i = \frac{\sum^{1} n_{ij} v_j}{TVR} \qquad v_j = \frac{\sum^{k} n_{ji} v_i}{TVB}$$

The FEI does not have a closed form solution; it is usually calculated by assuming an initial finite value for all weapons and solving the equation in a series of iterations until final values converge reflecting losses inflicted.

2. DIMENSION OF THE MEASURE: Ratio -- weighted by losses inflicted.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive value. Since losses are a function of several factors in the scenario, the output value of the FEI cannot be dissociated from the circumstances under which it was derived. The measure has a weakness in that a force that completely destroys the other without taking any losses is zero effective because the weapons destroyed had not obtained any value by inflicting losses.

4. RATIONALE FOR THE MEASURE: This is a complex form of loss exchange ratio with the advantage that weighted values are based on actual performance.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is suitable for measuring overall effectiveness of a mixed weapons force. In the referenced studies it was used to evaluate candidate armor-infantry mixes in terms of combined force firepower and survivability.

6. ASSOCIATED MEASURES: Proportion force destroyed. Loss exchange ratio.

7. REFERENCES:

ACN 07356, Tank, Antitank, Assault Weapon Systems Requirement Study, Phase III (TATAWS III); ACN 17018, Antitank Weapons Systems Requirement Study

RANKING OF OUTCOMES

1. DEFINITION OF THE MEASURE: Ranking of outcomes is a systematic procedure for assigning an evaluative value to a system by taking into account its relative rank in one or more relevant factors. Alternatives can simply be ranked first through last on one factor (e.g., degree of win), or on two factors (e.g., degree of win and resources expended) in matrix form:

Alternative One	Defeat Enemy	Hold FEBA	Fail to Hold
Most of Resources Remain	First rank	Second rank	Third rank
Normal Expenditure	Second rank	Third rank	Fourth rank
All Resources Expended	Third rank	Fourth rank	Last rank

Ranking can be on any number of factors by constructing matrices with more dimensions.

2. DIMENSION OF THE MEASURE: Ordinal -- Output is in terms of relative rank.

3. LIMITS ON THE RANGE OF THE MEASURE: The convention for establishing rank on each factor must be established. The procedure allows ties in the same factor.

4. RATIONALE FOR THE MEASURE: The usefulness of the measure is an orderly means of assigning rank.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to compare whole unit doctrinal and organizational systems.

6. ASSOCIATED MEASURES:
   Probability of success
   Degree of win

7. REFERENCES:
   No ACN - "A Method of Evaluating the Combat Effectiveness of a Tactical Information System in A Field Army," Lewis A. Leake and Roland V. Tiede, Research Analysis Corporation, McLean, Virginia

CONTROL MEASURES REQUIRED

1. <u>DEFINITION OF THE MEASURE</u>: Control measures required is a list of the control measures used in an action. Control measures include: line of departure, time of attack, intermediate objectives, direction of movement, axis of advance, attack position, formation, unit boundaries, coordinating points, trace of FEBA, defensive line, phase lines, delay positions, delay times, pyrotechnic signals, and so forth. Input is a list of all such measures used.

2. <u>DIMENSION OF THE MEASURE</u>: nominal -- output is a list of measures. Alternatively, the measure could be in a ratio form by dividing the number of control measures actually used by the number possible.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: As a nominal measure, this MOE is non - quantitative and can not be used in numerical comparisons. As a ratio measure it has the weakness of treating all control measures as of equal importance.

4. <u>RATIONALE FOR THE MEASURE</u>: This measure addresses difficulty of command and control. Its basis is the fact that more difficult command and control situations require more control measures, and therefore more control measures indicate such difficulty.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure is intended to evaluate command and control systems. In ACN 16819 it was used to compare night vision systems that were expected to make command and control in darkness easier and require fewer control measures. It could be used to evaluate a proposed change in doctrine or organization that could make control easier or more difficult.

6. <u>ASSOCIATED MEASURES</u>:
   - Changes per order
   - Repetitions per order
   - Percent orders with request for clarification

7. <u>REFERENCES</u>:
   - ACN 16819, STANO II Test

RATE OF ADVANCE

1. DEFINITION OF THE MEASURE: Rate of advance is the computation of distance per time period achieved in the advance. Distance input may be in the form of meters (or miles) advance of the forward point or square meters (or square miles) of territory taken. Time is in hours (or days). Relation of output to input is:

$$\text{rate of advance} = \frac{\text{total distance advanced}}{\text{elapsed time}}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is meters per hour, square meters per hour, square miles per day, or similar. If several observations are taken over time, it may be computed as the first derivative of cumulative distance for time, and expressed in the same terms.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure increases in usefulness as elapsed time increases. In its simple form it is constrained to a given time, but if several observations are taken to account for changing rates it may be used as a mean rate of advance.

4. RATIONALE FOR THE MEASURE: This is a direct measure of performance when the mission includes advance, as in the attack. It is considered superior to simple amount of advance which does not take into account a possible increase in difficulty of advance as distance from enemy decreases.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in comparing alternative concepts when advance is part of the primary mission. It is not usually useful alone, since cost of the advance must be taken into account by means of loss exchange ratio or other suitable measure.

6. ASSOCIATED MEASURES:
   - Amount of advance
   - Loss exchange ratio
   - Degree of win
   - Probability of mission accomplishment

7. REFERENCES:

ACN 15758, Army Small Arms Requirements Study I (ASARS I), Vol. IV, Jun 70

DISTANCE FROM OBJECTIVE

1. DEFINITION OF THE MEASURE: Distance from objective is the linear distance that an advancing unit is from its objective at a given time. Input data are the location of the advancing unit and location of the objective.

2. DIMENSION OF THE MEASURE: Interval -- Output is a distance in meters, kilometers or miles.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may assume any positive value. An absolute value in this form is not usually valuable unless collected over time for a rate of change in distance from objective (rate of advance) or other utilization in the form of a ratio.

4. RATIONALE FOR THE MEASURE: Distance from objective is assumed to be an indication of the effectiveness of a unit in closing upon an objective.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to distinguish among candidates in their effectiveness at reducing the distance to the objective in a given time period and under specified circumstances.

6. ASSOCIATED MEASURES:
   - Rate of advance
   - Range of engagement

7. REFERENCES:

ACN 15758, Army Small Arms Requirements Study I (ASARS I) - Jun 70

RANGE OF ENGAGEMENT

1. DEFINITION OF THE MEASURE: Range of engagement is the distance between opposing forces when either side initiates firing. Data input is the location of each force. Location may be measured at forward edges or at centers of mass. Relation of output to input is the simple measurement (or estimate) of distance between the two location inputs.

2. DIMENSION OF THE MEASURE: Interval -- A linear measure of distance. Unit of measure of output is meters, kilometers, or other suitable measure of tactical distance. (With several measures, the MOE may be a ratio in the form of "mean range of engagement".)

3. LIMITS ON THE RANGE OF THE MEASURE: Output may assume any positive value. Resolution of the measure depends on the accuracy of locations and refinement of the unit of measure.

4. RATIONALE FOR THE MEASURE: Range of engagement measures effectiveness when the mission includes the intent to engage as late as possible (as in the attack) or as early as possible (as in the defense).

5. DECISIONAL RELEVANCE OF THE MEASURE: This is a measure of the success of a unit in causing or preventing early engagement.

6. ASSOCIATED MEASURES:
   - Time to detection
   - Mean detection range
   - Probability of detection

7. REFERENCES:
   ACN 17874, Mechanized Rifle Company STANO Test - Nov 71

AREA ACQUIRED

1. DEFINITION OF THE MEASURE: Area acquired is the amount of area taken under tactical circumstances. Input data are the amount of area taken in square meters, square kilometers, or square miles, and the length of time required. Relation of output to input is:

area acquired = area held at end time minus area held at start time

2. DIMENSION OF THE MEASURE: interval -- amount of area in terms of square kilometers or other suitable unit of measure. The measure could be in a ratio form such as "rate of area acquisition" by taking the first derivative of cumulative area acquired as a function of time, or "proportion of assigned area taken".

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any value up to the total amount of area assigned as the objective. The data input may be complicated by the necessity to measure many small irregular-shaped areas. The measure may be misleading if the primary mission is not to take area. This measure is related to rate of advance.

4. RATIONALE FOR THE MEASURE: The measure addresses accomplishment of mission directly if the mission is to take territory. Otherwise, it may still be a useful supplementary measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure can be used to evaluate a system when the primary mission of the system is to take area.

6. ASSOCIATED MEASURES:
- Rate of advance
- Distance from objective
- Percent area coverage
- Probability of success

7. REFERENCES:
ACN 05546 Army Air Mobility Evaluation (ARAME), 15 Feb 65

PERCENT MISSIONS WITHIN TIME

1. DEFINITION OF THE MEASURE: Percent missions within time is the percentage of missions accomplished within the suspense time ordered, out of all missions ordered. Input data are the number of missions accomplished within time ordered and the number of missions ordered. (A mission with no time limit is counted as accomplished within time if it is accomplished, regardless of time taken). Each mission has its own time limit, as set by the commander ordering the mission. Relation of output to input is:

$$\text{percent missions within time} = \frac{\text{number msns completed within time ordered}}{\text{number msns ordered}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of percent of missions.

3. LIMITS ON THE RANGE OF THE MEASURE: A substantial portion of the missions ordered must have a specified time limit, for a meaningful measure, and the measure becomes more meaningful as the number of missions increases. The output can assume any value from zero to one hundred percent, but the percentage will be partly inflated by the missions with no time limit.

4. RATIONALE FOR THE MEASURE: This is a direct measure of timeliness which capitalizes on the commander setting the criterion for each mission.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used as an indicator of timeliness in any situation where suspense times are ordinarily set. In the referred study it was used to measure timeliness of emplacing unattended ground sensors. It could be used to measure timeliness of taking intermediate objectives, filing reports, completing moves, firing artillery missions, completing patrols, negotiating obstacles, delivering messages, or any military mission that normally has a suspense time.

6. ASSOCIATED MEASURES:

- Time to acquisition
- Mean time to completion
- Percent missions accomplished
- Probability of success

7. REFERENCES:

ACN 15353, Field Evaluation HIGH GEAR - Jun 69

TIME TO MISSION COMPLETION

1. DEFINITION OF THE MEASURE: Time to mission completion is the elapsed time from start to end of a stated mission. Input data are the initiation and completion times, and output is the subtracted difference:

time to completion = (end time) - (start time)

2. DIMENSION OF THE MEASURE: Interval -- output is an elapsed time in seconds, minutes, hours, days, or as appropriate. It may be used in the ratio form, "mean time to completion".

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be any positive expression of time. Resolution of the measure depends on the precision of measuring time. Completion must be defined and the measure can not be dissociated from the definition.

4. RATIONALE FOR THE MEASURE: This is the simplest and most direct measure of timeliness. It is usually inexpensive to take, although more difficult than "percent missions completed within time".

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is used to evaluate any sort of system in regard to timeliness. It is stated here in general form, but is more often stated in specific form such as: time to complete move, time to adjust fire, time to defeat, time to resupply, time to destroy, planning time, time on target, and so forth.

6. ASSOCIATED MEASURES:

Percent missions completed within time
Percent moves within time order
Time to occupy positions
Time to adjust fire
Time to resupply

7. REFERENCES:

ACN 13233, Land Navigation Systems Troop Test, Jul 70
ACN 13925, METOXE Test, Dec 69
ACN 17494, Divisional War Game Model
No ACN, Mobility System Planning Compendium
No ACN, "Candidate MOE for Air Strike Systems," Naval Weapons Center document #4687

LOSS EXCHANGE RATIO

1. DEFINITION OF THE MEASURE: Loss exchange ratio is the quotient of red losses divided by blue losses. Input data are number counts of losses for each side. The relation of output to input is:

$$\text{loss exchange ratio} = \frac{\text{number of red losses}}{\text{number of blue losses}}$$

2. DIMENSION OF THE MEASURE: Ratio of two number counts -- The unit of measure of the output is a pure number. Output may be in the form of a ratio (1:10), proportion (.10), or fraction (1/10).

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful if the number of blue losses is zero, and not very useful if losses on both sides are low.

4. RATIONALE FOR THE MEASURE: This is a measure of blue effectiveness taking into account both blue's capability of inflicting losses and capability of surviving red actions.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used in the situation where both forces have the primary mission of destroying the other. It is less useful if either side has some other primary mission. It is difficult to apply if both forces are heterogeneous such that unlike elements have to be combined to yield the input values. It can be used to distinguish among compared candidates for doctrine, organization, materiel, training, or logistical support because it combines aspects of both offensive and defensive capability.

6. ASSOCIATED MOE'S:
   - Relative loss exchange ratio
   - Rate of attrition
   - Survivability Index

7. REFERENCES:

ACN 03010, Infantry Rifle Unit Study - 75.
ACN 18171, Attack Helicopter-Daylight Defense Field Experiment.
ACN 05546, Army Air Mobility Evaluation, Feb 65.
ACN 17419, Employment of Attack Helicopters to Defeat Armor, Apr 71.
No ACN, HELL TANK Exercise, UK Defense Establishment Memo #2/69, Jan 69.

RELATIVE LOSS EXCHANGE RATIO

1. DEFINITION OF THE MEASURE: The relative loss exchange ratio is the quotient of proportion of red losses divided by proportion of blue losses. Input data are: red initial strength, blue initial strength, red losses, and blue losses. The relation of input to output is:

$$\text{relative loss exchange ratio} = \frac{\dfrac{\text{red casualties}}{\text{red initial strength}}}{\dfrac{\text{blue casualties}}{\text{blue initial strength}}}$$

2. DIMENSION OF THE MEASURE: Ratio of two ratio's -- The unit of measure of the output is a pure number. The unit of measure for all four input values is number of personnel, tanks, major weapons, subordinate units, or other suitable count of force size.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful if any of the four input variables is zero, and not very useful if either of the initial strength values is quite small.

4. RATIONALE FOR THE MEASURE: The relative loss exchange ratio is a measure of Blue effectiveness taking two major factors into account. The numerator is an indicator of Blue destructive capability; the denominator is an indicator of Blue survivability. The combination approaches an overall indication of Blue combat effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used in the situation where both forces have the primary mission of destroying the other. It is still useful, but less so, if either force has any other primary mission. It is difficult to apply if forces are quite heterogeneous such that unlike elements have to be combined to yield any of the input values. It can be used to distinquish among competing candidates for doctrine, organization, materiel, training, or logistical support when attribution of force strength is a significant consideration.

6. ASSOCIATED MOE'S:

Loss exchange ratio
Rate of attrition
Survivability Index

7. REFERENCES:

ACN 03010, Infantry Rifle Unit Study - 75
ACN 17494, Development of a Divisional War Game Model, Dec 71.

BLUE TO RED FIRST ACQUISITION

1. DEFINITION OF THE MEASURE: Blue to red first acquisitions is the ratio of first acquisitions by each side in the case where both sides start attempting to acquire each other simultaneously. Acquisitions are detection and proper identification; first fire, first round on target are components of engagement. The measure can be left in the form of blue:red (for example, 17 blue first detections to 13 red first detections) or the quotient. Ties are not included. Relation of output to input is:

$$\text{blue:red first acquisitions} = \frac{\text{blue first acquisitions}}{\text{red first acquisitions}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Unit of measure of the output is an ordered pair of first acquisitions (or can be the pure number quotient).

3. LIMITS ON THE RANGE OF THE MEASURE: The output values can be zero or any positive number. The quotient would not be meaningful if the denominator is zero, and the measure is not very useful when both numerator and denominator are small numbers. One or the other should be large enough to represent a stable sample of all engagements.

4. RATIONALE FOR THE MEASURE: This measure addresses an important component of acquisition in which both sides begin attempts to acquire simultaneously. In the form of first fires, it relates to survivability versus firepower.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used as an indication of superior acquisition in the case where both sides competitively attempt to acquire simultaneously. In the referenced experiment timing started when helicopters suddenly exposed themselves to ground air defense vehicles and both sides attempted to detect, identify and bring fire on the other first. It could be used in any sort of meeting engagement situation.

6. ASSOCIATED MEASURES:

Loss exchange ratio
Time to detect
Time to fire

7. REFERENCES:

ACN 18171, Attack Helicopter-Daylight Defense Field Experiment

RELATIVE AMMO EXPENDITURE TO CASUALTIES RATIO

1. DEFINITION OF THE MEASURE: The relative ammunition expenditure to casualties ratio is the quotient of proportion of casualties to proportion of ammunition expended. Input values are counts of force size and losses, and ammunition. Relation of output to input is:

relative ammo expenditure to casualties ratio =

$$\frac{\dfrac{\text{first force casualties}}{\text{first force initial strength}}}{\dfrac{\text{second force ammo expended}}{\text{second force basic ammo load}}}$$

2. DIMENSION OF THE MEASURE: Ratio of two ratios -- the unit of output is a pure number, or may be considered a complex form of casualties per ammunition expenditure.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful if any of the four input values is zero, and not very useful if the initial strength or basic load is a small number.

4. RATIONALE FOR THE MEASURE: The relative ammunition to casualties ratio is an indicator of firepower effectiveness if the casualties are the opposing force, or is an indicator of survivability if the casualties are the friendly force. It is superior to the absolute casualties per round ratio in that proportions of initial values are taken into consideration, so that some trade-off of production and cost is considered.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure could be useful in the case of a decision involving a firepower situation which must take into account both firepower and survivability.

6. ASSOCIATED MEASURES:

Absolute casualties per round ratio
Expected remaining tank killing capability
Loss exchange ratio

7. REFERENCES:

None; this is a potential measure.

RED CASUALTIES PER INITIAL BLUE STRENGTH

1. <u>DEFINITION OF THE MEASURE</u>: Red casualties per initial blue strength is the ratio of number count of red losses to number count of initial blue force size. Input values are any suitable count of force strength such as personnel, tanks, weapons, or other. Relation of output to input is:

$$\text{red casualties per initial blue strength} = \frac{\text{number of red losses}}{\text{number count of initial blue force size}}$$

2. <u>DIMENSION OF THE MEASURE</u>: Ratio -- the output is a ratio in terms of red losses per initial blue force size. In this form it is a dimensionless ratio for a stated time period. Dimension could be added by taking incremental losses and remaining strength at periodic time points and using the measure as a rate of red casualties to remaining blue force strength.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: The measure is not meaningful if the numerator is zero, and not very useful if the denominator is a small number. The measure is difficult to apply when forces are relatively heterogeneous because the number counts of strength and losses would have to convert all input into a common form.

4. <u>RATIONALE FOR THE MEASURE</u>: This MOE is an indicator of "kill productivity." It was used in a study to discriminate between candidate organizations with different mixes of the same weapon types to see if there was a difference in kill productivity due to mix. It is primarily concerned with firepower and is not appropriate to most other aspects of combat operations.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>. The measure could be quite useful in order ranking competing concepts in terms of kill productivity holding cost relatively constant. It can yield an interval measure in the sense of how much better or poorer one candidate is, but would have to be handled partly judgementally since the distribution of values with differing denominators is probably not linear.

6. <u>ASSOCIATED MEASURES</u>:
   - Rounds expended per casualty
   - Loss exchange ratio

7. <u>REFERENCES</u>:
   - ACN 03010, Infantry Rifle Unit Study - 75

CASUALTY RATE

1. DEFINITION OF THE MEASURE: Casualty rate is the number of casualties per time period. There are two input values, number counts of casualties and number of equal time periods. Relation of input to output is:

$$\text{casualty rate} = \frac{\text{total number of casualties}}{\text{number of time periods}}$$

Alternatively, the casualty rate might be computed as the arithmetic average of the number counts of each time period, or as the first derivative of the cumulative number of casualties as a function of time.

2. DIMENSION OF THE MEASURE: Ratio -- Output in terms of casualties per day, or other time unit.

3. LIMITS ON THE RANGE OF THE MEASURE: The usefulness of the measure increases as the amount of time in the denominator increases. The measure is more refined as the unit of measure of time decreases. The rate may change over time, so the output can not be dissociated from the time period involved.

4. RATIONALE FOR THE MEASURE: When enemy casualty rate is computed, this is a measure of firepower. In the referenced study it was used as an indicator of small arms effectiveness. When friendly casualty rate is used, it can indicate survivability.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare effectiveness of systems over time when the systems include a mission of inflicting casualties on the enemy or preventing friendly casualties.

6. ASSOCIATED MEASURES:
   - Proportion of blue losses
   - Proportion of red losses
   - Loss exchange ratio
   - Relative loss exchange ratio

7. REFERENCES:

ACN 15758, Army Small Arms Requirements Study I (ASARS I) - Jun 70

ATTRITION RATE

1. DEFINITION OF THE MEASURE: Attrition rate is the amount of enemy capability neutralized per time period. It is usually stated in terms of the proportion of enemy capability neutralized. Input data are chronological time and either amount of destruction of proportion of destruction. The computation is usually the proportion of enemy destroyed in a given time period, but may be the first derivative of cumulative destruction as a function of time. Relation of output to input is:

$$\text{attrition rate} = \frac{\text{amount or proportion of enemy destroyed}}{\text{time period}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a rate in terms of destruction per time period, such as, 5% destruction per hour, or 20 tanks destroyed per day.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive value up to the total capability of the enemy. Since rates may change over time, the output value may not be dissociated from the time period involved. It is often difficult to supply input value for total capability.

4. RATIONALE FOR THE MEASURE: This measure addresses fire power directly taking into account both amount and timeliness of destruction.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be applied to evaluations of inflicting casualties (casualty rate), destroying targets (target destruction rate), reduction in logistical flow, or any other situation involving effectiveness of fire power.

6. ASSOCIATED MEASURES:
   - Casualty rate
   - Target destruction rate
   - Expected remaining force size

7. REFERENCES:
No ACN - "Candidate Measures of Effectiveness for Air Strike Systems" Naval Weapons Center #TP4687, China Lake, Cal., Sep 69
ACN 17494, Development of a Divisional War Game Model, Dec 71
ACN 15758, Army Small Arms Requirements Study - I, Jun 70
ACN 03010, Infantry Rifle Unit Study - 75

DEGREE OF BLUE WIN

1. <u>DEFINITION OF THE MEASURE</u>: The degree of blue win is an index number describing the degree to which blue stays within its breakpoint in casualties in an engagement. The input data are number of blue casualties experienced and number of blue casualties allowable, both expressed in a suitable number count of force size such as personnel, tanks, weapons, or other. Relation of output to input is:

degree of blue win =

$$1 - \left[\frac{\text{actual number of blue casualties}}{\text{specified breakpoint (maximum allowable blue casualties)}}\right]$$

2. <u>DIMENSION OF THE MEASURE</u>: Index number -- the output measure is a difference between unity and the proportion of actual casualties to casualties allowable. The unit of measure of output is, in effect, the remaining allowable proportion of casualties.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: The specified breakpoint must be a value greater than zero. The value of the measure can be + 1 or any lesser value. The best possible score is positive one. All positive values are favorable, and zero may indicate a standoff. Negative values might best be interpreted as degree of blue loss. (The lowest possible score is the negative value of initial blue force size minus one.)

4. <u>RATIONALE FOR THE MEASURE</u>: This is a more refined measure of blue win than simple win/loss dichotomy or probability of win. In the referenced study it was used to supplement grosser measures for breaking ties in rank ordering of candidate alternatives. If applied across a number of engagements it can be used as average degree of blue win.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure can be used when blue wins is the primary objective. It would ordinarily be used in conjunction with other measures of blue win, such as probability of win, to further refine the measure. Its main advantage is that it takes blue survivability or cost of winning into account.

6. <u>ASSOCIATED MEASURES</u>:
   - Probability of win
   - Loss exchange ratio
   - Degree of red loss

7. <u>REFERENCES</u>:
   ACN 03010, Infantry Rifle Unit Study - 75

DEGREE OF RED LOSS

1. DEFINITION OF THE MEASURE: The degree of red loss is a ratio expressing the degree to which red exceeds its breakpoint in casualties in an engagement. The input data are number of red casualties experienced and number of red casualties allowable, both expressed in a suitable count of force size such as personnel, tanks, weapons, or other. Relation of output to input is:

$$\text{degree of red loss} = \frac{\text{actual number of red casualties}}{\text{specified breakpoint (maximum allowable red casualties)}}$$

2. DIMENSION OF THE MEASURE: Ratio -- the output measure is a pure number expressing the proportion of actual red casualties to allowable number of red casualties. Or, in a slightly different form, (multiplying proportion by 100%) it is the percentage of allowable casualties.

3. LIMITS ON THE RANGE OF THE MEASURE: The breakpoint must be specified at a value greater than zero for a meaningful measure. The value can be zero or any positive number. It is noted that the value will be less than 1.0 (or 100%) if the engagement ends before red reaches its breakpoint. A fractional value may be interpreted as a "partial loss" for red, while a zero value indicates no loss but may be a standoff.

4. RATIONALE FOR THE MEASURE: The measure is a more refined indicator of red loss than just a simple win/loss dichotomy. The measure takes survivability into account and also places values on partial losses. In the referenced study it was used to supplement grosser measures of win/loss for purposes of rank ordering alternative candidates.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used for engagements in which blue win is the primary objective and is useful in discriminating among different red losses. It would ordinarily be used in conjunction with a measure of blue probability of win to further refine the measure of equal probabilities.

6. ASSOCIATED MEASURES:
   - Probability of win
   - Degree of blue win
   - Loss exchange ratio

7. REFERENCES:

ACN 03010, Infantry Rifle Unit Study - 75

RATIO OF BLUE/RED SURVIVORS

1. DEFINITION OF THE MEASURE: The ratio of blue/red survivors is the number of blue survivors divided by the number of red survivors. Input are the numbers of surviving personnel (or tanks, aircraft, subordinate units) for both sides. Relation of output to input is:

$$\text{Ratio of blue/red survivors} = \frac{\text{number of blue survivors}}{\text{number of red survivors}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a pure number expressing the ratio. In the slightly more complex form "relative ratio of blue/red survivors" it is a ratio of two ratios, the two ratios being percent of each force surviving.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive value. A pure ratio measure like this suffers from being a performance measure rather than a true measure of effectiveness. The relative ratio is better in this sense.

4. RATIONALE FOR THE MEASURE: The measure gives an indication of the relative status of two forces.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is best used as an input to higher level measures such as proportion of engagements won, or probability of success. It has, however, been used to compare systems on survivability when both sides started with equal force size.

6. ASSOCIATED MEASURES:
   - Percent engagement won
   - Probability of success
   - Probability of survival
   - Loss exchange ratio
   - Relative loss exchange ratio

7. REFERENCES:

No ACN - "Parametric Design/Cost Effectiveness Study for a Mechanized Infantry Combat Vehicle - 1970, Connell Laboratory Report #GM 2144-H-1a, Nov 66

No ACN - Article: "Aerial Blocking Force," Army Aviation, Apr 72

ORGANIZATION

SPAN OF COMMAND

1. DEFINITION OF THE MEASURE: Span of command is the number count of next lower echelon subordinate elements reporting directly to a command. Input is the simple number count:

$$\text{span of command} = \sum_{i=1}^{n}(\text{each directly subordinate element})$$

2. DIMENSION OF THE MEASURE: Interval -- Output is a number of commands.

3. LIMITS ON THE RANGE OF THE MEASURE: The output is a positive integer greater than one.

4. RATIONALE FOR THE MEASURE: The measure is intended to guage probable difficulty in command and control due to organizational structure. It is not truly a measure of effectiveness by itself but only an indicator of possible difficulty. Too great a span would probably result in control difficulties.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is an indicator of probable difficulty in evaluating proposed organizational structures. Its best application is in aiding identification of causes of problems as determined by better measures.

6. ASSOCIATED MEASURES:
   - Repetitions per order
   - Mean number transmissions required
   - Changes per order

7. REFERENCES:
   - None - this is a potential measure

TOP-TO-BOTTOM DISSEMINATION TIME

1. DEFINITION OF THE MEASURE: Top-to-bottom dissemination time is the time required to disseminate any item of information from the headquarters of an organization to the individual troops at the lowest echelon. Input data are the time dissemination starts and the time all the troops have received the information. Information may be an order, directive, change of password, or any matter requiring total dissemination. Relation of output to input is the subtracted difference:

dissemination time = (time last individual receives item) - (time dissemination started)

2. DIMENSION OF THE MEASURE: Interval -- measure is an elapsed time. If several disseminations are observed the measure may be in ratio forms, such as "mean top-to-bottom dissemination time."

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The measure may be modified to the time that a given percentage of troops have received the information or until a set of pre-selected individuals are reached. In either of these cases the measure would be less expensive to take.

4. RATIONALE FOR THE MEASURE: The measure is presumed to evaluate the effectiveness of organization. It addresses a command, control, and communications function directly but with the intent of ascertaining whether the size and structure of the organization allow clear channels of rapid dissemination.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to evaluate alternative proposed organizational structures. It might apply to guaging effectiveness of training in respect to command and control.

6. ASSOCIATED MEASURES:
   - Percent personnel informed
   - Planning time forwarded
   - Repetitions per order

7. REFERENCES:
   None - this is a proposed measure

REPORTING TIME

1. DEFINITION OF THE MEASURE: Reporting time is the elapsed time from occurrence of a reportable event to submission of the report. Input data are the times of occurrence and submission. Relation of output to input is:

reporting time = time of submission minus time of occurrence

2. DIMENSION OF THE MEASURE: Interval measure -- Output is elapsed time in terms of days, hours, and minutes.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. Resolution of the measure depends on the precision of timing. A convention has to be established for reports that are periodic, or otherwise routine, for the appropriate occurrence time. The convention is usually the end of the time period covered.

4. RATIONALE FOR THE MEASURE: This measure combines several aspects of reporting time such as the time to collect information, time to prepare the report in the proper format, staffing time, and dissemination time. The speed of reporting is assumed to indicate efficiency of command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable to any of numerous kinds of reports or to all reports combined from a given organization. It may be used to compare organizations or other command, control, and communications systems in effectiveness.

6. ASSOCIATED MEASURES:

- Planning time
- Pct messages received
- Response time
- Pct mission within time ordered
- Amount of information

7. REFERENCES:

- ACN 00004, A Method for Integration of Mediacl Accounting Reporting Supply and Regulating of the Army in the Field into ADSAF - CS_3 Program.
- ACN 17036, MASSTER III Test, Oct 71.
- ACN 06930, Troop Test Frontier Shield, May 66.

PERCENT REPORTS ON TIME

1. DEFINITION OF THE MEASURE: Percent reports on time is the percentage of all required reports that are submitted by the required time. Reports that have no required time are counted as on time regardless of delay. Input data are the number of reports submitted late and the total number of required reports. Relation of output to input is:

$$\text{pct rpts on time} = \frac{\text{number required reports minus number late reports}}{\text{number required reports}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a ratio in the form of percentage of reports.

3. LIMITS ON THE RANGE OF THE MEASURE: Percentage can vary from zero to one hundred per cent. The measure is diluted somewhat by the inclusion of reports which have no suspense time. The measure is somewhat gross in that it treats all late reports in the same class regardless of whether they are slightly late or very late, and ignores differences in importance of reports.

4. RATIONALE FOR THE MEASURE: The measure is an indicator of one aspect of command, control, and communications, timeliness of reporting. It is based on the theorem that timely reporting is essential to effective command. While the measure is somewhat gross it is very convenient and inexpensive to take.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be applied to evaluation or comparison of command and control systems, especially alternative organizations. This measure would ordinarily not stand alone but be used in conjunction with other measures concerning reporting and communications.

6. ASSOCIATED MEASURES:
   Pct messages received
   Reporting time

7. REFERENCES:
   None, this is a proposed potential measure.

ON-ROAD MOVEMENT RATE COMPATIBILITY

1. DEFINITION OF THE MEASURE: On-road movement rate compatibility is the difference between mean on-road movement rate of all vehicle types in the organization and the on-road rate of the slowest vehicle. Input data are the on-road rates of each type of ground vehicle in the organization. The relation between output and input is:

$$\text{on-road movement rate compatibility} = \frac{\sum_{i=1}^{n} R_i}{n} - R_s$$

Where: R_1 = on-road movement rate of first vehicle type

R_2 = on-road movement rate of second vehicle type

R_n = on-road movement rate of last vehicle type

R_s = on-road movement rate of slowest vehicle type

2. DIMENSION OF THE MEASURE: Difference between two rates -- Output value is a rate, in terms of kilometers per hour or other suitable expression of rate.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume a value from zero to any positive number. Input values are not limited but must be expressed in terms of the same definition of rate. The measure is most meaningful when measures are most refined, that is, kilometers per hour is more meaningful than kilometers per day, because rounding off of cruder measures sacrifices some of the measure.

4. RATIONALE FOR THE MEASURE: This is a measure of one aspect of efficiency of organization. An organization's vehicle mix should be compatible in the sense that no one type vehicle should detract seriously from the overall movement rate of an organization. While movement rate itself is a measure of mobility, compatibility of movement rates may best be considered a measure of soundness of organization. Rate compatibility could be measured in different ways, such as the difference between the slowest and second slowest vehicle or in average deviation of rates from the mean. The difference between the mean rate and the slowest rate is chosen as meaningful for military purposes because it is associated with the most critical immediate problem.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful for comparing competing proposed organizations when mobility is one of the aspects of comparison.

6. ASSOCIATED MEASURES:

Cross-country rates compatibility	Payload capacity
Movement rate	Turn-around time

7. REFERENCES:

ACN 16495, Family of Army Vehicles Study (FAVS)

CROSS-COUNTRY RATE COMPATIBILITY

1. DEFINITION OF THE MEASURE: Cross-country rate compatibility is the difference between mean cross-country rate of all vehicle types in the organization and the cross-country rate of the slowest vehicle. Input data are the cross-country rates of each type of ground vehicle in the organization. The relation between output and input is:

$$\text{cross-country rate compatibility} = \frac{\sum_{i=1}^{n} R_i}{n} - R_s$$

Where: R_1 = cross-country rate of first vehicle type

R_2 = cross-country rate of second vehicle type

R_n = cross-country rate of last vehicle type

R_s = cross-country rate of slowest vehicle type

2. DIMENSION OF THE MEASURE: Difference in two rates -- Output value is a rate in terms of kilometers per hour or other suitable expression of rate.

3. LIMITS ON THE RANGE OF THE MEASURE: There is no limit on the output value; it may be zero or any positive number. Input values are not limited, but must be expressed in terms of the same definition of rate. The measure is most meaningful when measures are most refined, that is, kilometers per hour is more meaningful than kilometers per day, because rounding off of cruder measures sacrifices some of the measure.

4. RATIONALE FOR THE MEASURE: This is a measure of one aspect of efficiency of organization. An organization's vehicle mix should be compatible in the sense that no one type vehicle should detract seriously from the overall movement rate of an organization. While movement rate itself is a measure of mobility, compatibility of movement rates is an indicator of soundness of organization between fastest and slowest vehicles, variation of rates or some comparison of the slowest rate to others. The difference between the mean rate and the slowest rate is selected as the most meaningful in the military sense of identifying critical restraints.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful for comparing competing hypotheses of organization when mobility is one of the aspects of comparison.

6. ASSOCIATED MEASURES:

- Movement rate
- Payload capacity
- Turn-around time
- On-road movement rates compatibility

7. REFERENCES:

ACN 16495, Family of Army Vehicles Study (FAVS)

PERCENT CIRCUITS SOLE USER

1. DEFINITION OF THE MEASURE: Percent circuits sole user is the percentage of all telephone wire loops dedicated to one sole user. Input data are the number of loops in the organization and the number of these reserved for designated sole users. Relation of output to input is:

$$\text{percent circuits sole user} = \frac{\text{number sole user circuits}}{\text{total number circuits}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is a percentage, in terms of percent of circuits.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. It could not reasonably be a very high percentage unless general users were left without access.

4. RATIONALE FOR THE MEASURE: This measure is intended to address one aspect of organizational structure effectiveness, namely the use of one means of compensating for faulty organization. In principle sole user circuits are undesirable because sole user lines get a much lower rate of use than general user lines. Sole use circuits are employed when difficulties in the structure of an organization require special means of communication beyond normal considerations. This measure is based on the theorem that an ideal organization would require no sole user circuits.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate the effectiveness of hypothesized organizational structures.

6. ASSOCIATED MEASURES:
   - Transmissions completed
   - Message backlog
   - Span of control
   - Dissemination time

7. REFERENCES:

ACN 03210, TASS Field Evaluation, Jun 71

AREA COVERAGE

1. DEFINITION OF THE MEASURE: Area coverage is the amount of area under influence. In surveillance coverage it is the amount of area in which surveillance is adequate; in fire coverage it is the amount of area in which fire can be delivered. It is necessary to define adequate degree of influence. Input data are the dimensions of the area under coverage. If the pattern of coverage is circular only a radius is needed. In most cases a sum of small square areas is the input in the form:

$$\text{area coverage} = \sum_{i=1}^{n} (l_i w_i)$$

where: l=length
w=width

2. DIMENSION OF THE MEASURE: Interval -- Output is a simple total of area covered in the form of square meters, square miles, or similar.

3. LIMITS ON THE RANGE OF THE MEASURE: The resolution of the measure is limited by the unit of measure of input, and the precision with which small areas are blocked before totaling. Care must be taken, especially in circular area, to account for dead space not covered. The output value is bonded to the circumstances under which it was measured and can not be dissociated from these conditions.

4. RATIONALE FOR THE MEASURE: This is a direct measure of the amount of surveillance or fire potential capability.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful whenever surveillance of fire control of an area is a part of the system objectives, for comparison of such systems. It could be used in other types of systems evaluations, for example, the area covered by a medical evacuation system, the area within one day's movement of a unit, or the area free of enemy insurgency forces.

6. ASSOCIATED MEASURES:
   - Maximum range
   - Maximum effective range
   - Percent area coverage

7. REFERENCES:

ACN 17874, Mechanized Rifle Company STANO Test - Nov 71

PERCENT AREA COVERAGE

1. DEFINITION OF THE MEASURE: Percent area coverage is the percentage of a given area which is under influence of the system whose effectiveness is measured. For example, it may be the percent of a battalion's AO that is within unobstructed range of mortar fire. Input data are area of coverage and area assigned. Both input values are in terms of squa·e meters, square kilometers, square miles, or similar. Relation of output to input is:

$$\text{percent area coverage} = \frac{\text{area coverage}}{\text{area assigned}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage of area, in square meters, kilometers, or appropriate unit of measure of area.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may vary from zero to one hundred percent inclusive. Resolution of the measure depends on refinement of unit of measure.

4. RATIONALE FOR THE MEASURE: This measure addresses the amount of effectiveness of any system that has among its objectives the influences of an area. It is somewhat more refined than simple area coverage because it takes into account the goal for coverage.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative systems with an area coverage mission. Systems with area coverage objectives include surveillance devices or units, weapons or unit firepower potential, unit mobility within a given time, medical evacuation team, communications space, and pacification program.

6. ASSOCIATED MEASURES:

Maximum range
Maximum effective range
Area coverage

7. REFERENCES:

ACN 17874, Mechanized Rifle Company STANO Test - Nov 71.
ACN 17494, Development of a Divisional War Game Model, Dec 71.

NUMBER LOSSES

1. DEFINITION OF THE MEASURE: Number losses is a simple number count of losses inflicted on a force. Input data is a count of losses of a certain type (personnel, antitank weapons, tanks, radars, aircraft, subordinate elements, or any suitable number count of force size) or a combination of number counts. Relation of output to input is a simple sum, or a total of weighted sums:

$$\text{number losses} = \sum(\text{each loss of a type}) \text{ or } = \sum\left[(\text{sum of losses, each type})(\text{wt})\right]$$

2. DIMENSION OF THE MEASURE: interval -- a number count, or weighted number count

3. LIMITS ON THE RANGE OF THE MEASURE: The measure may be zero or any positive integer limited only by the total force size, in the simpler case. In the weighted case, it is zero or any positive number up to force size, but may be fractional.

4. RATIONALE FOR THE MEASURE: This is the simplest, most direct measure of the effectiveness of firepower, or of survivability. But since it is an absolute number it cannot be dissociated from the exact circumstances under which it was derived.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare systems on firepower or survivability when the competing systems are tried under precisely the same conditions. It is usually used as part of a non-absolute measure such as loss exchange ratio, proportion of force surviving, or loss rate.

6. ASSOCIATED MEASURES:
   - Loss rate
   - Casualty rate
   - Percent loss rate
   - Loss exchange ratio
   - Relative loss exchange ratio
   - Proportion of force surviving

7. REFERENCES:
   - ACN 15724 - Optimum Mix of Arty Units, 1975-80
   - ACN 13708 - TACFIRE Cost Effectiveness Study
   - ACN 06488 - Artillery Study 1970-75
   - ACN 12757 - Secondary Armament for the MBT - 70

NUMBER CASUALTIES

1. DEFINITION OF THE MEASURE: Number casualties is the number count of personnel casualties inflicted. Also called "personnel losses," "body count", "red casualties", "blue casualties", or "personnel kill." The measure may be limited to kills or include both kills and any other type of casualties that immediately cost loss of manpower.

2. DIMENSION OF THE MEASURE: interval measure -- a number count of personnel casualties

3. LIMITS ON THE RANGE OF THE MEASURE: Output can be zero or any positive integer. Like all number counts the use of the output value cannot be dissociated from the time period and other circumstances of its generation.

4. RATIONALE FOR THE MEASURE: This measure is one of the most direct indicators of directed firepower.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable in any situation where one or both sides has among its mission the destruction of the opposing force.

6. ASSOCIATED MEASURES:

Loss exchange ratio	Attrition rate
Relative loss exchange ratio	Losses inflicted

7. REFERENCES:

ACN 15724, Optimum Mix of Artillery Units (1975-1980)
ACN 07346, Optimum Mix of Artillery Units (1971-1975)
ACN 13138, Divisional Artillery Study
ACN 13708, TACFIRE Cost Effectiveness Study
ACN 06488, Artillery (1970-1975)
ACN 03434, Lance Cost-Effectiveness Study
ACN 15137, Support of Airmobile Operations through Destruction Enemy Air Defense Systems

PERCENT CASUALTIES

1. DEFINITION OF THE MEASURE: Percent casualties is the percentage of a force that become casualties. Input data are the number of personnel in the initial force and number of casualties. Relation of output to input is:

$$\text{percent casualties} = \frac{\text{number casualties}}{\text{number in intial force}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- a percentage of force size

3. LIMITS ON THE RANGE OF THE MEASURE: Output can vary from zero to one hundred percent.

4. RATIONALE FOR THE MEASURE: This is a direct measure of the loss suffered. When applied to the enemy force it addresses effectiveness of friendly operations; when applied to the friendly force it addresses resistence to enemy operations.

5. DECISIONAL RELEVANCE OF THE MEASURE: The masure is used to evaluate total force effectiveness when destruction of the opposing force is the primary mission of both sides.

6. ASSOCIATED MEASURES:

Percent target destroyed	Attrition rate
Remaining force size	Casualty rate

7. REFERENCES:

ACN 13338 - NUWAR War Game, 1970-1975

LOSS RATE

1. DEFINITION OF THE MEASURE: Loss rate, or casualty rate, is the number of losses per time period or mission. Losses are measured in number of personnel, tanks, aircraft, length of rail, buildings, subordinate units, or other suitable unit of measure of force size. Relation of output to input is:

$$\text{Loss rate (or casualty rate)} = \frac{\textbf{number of losses (or casualties)}}{\textbf{elapsed time (or missions)}}$$

Alternatively, if data are available for cumulative losses as a function of time, the loss may be computed as the first derivative.

2. DIMENSION OF THE MEASURE: Ratio -- output is a rate in terms of casualties per minute, tanks per hour, aircraft per day, oil tanks per sortie, or as appropriate.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful until at least one loss has been inflicted, and increases in usefulness as the elapsed time (or number of missions) increases.

4. RATIONALE FOR THE MEASURE: The measure addresses how much firepower must be applied to achieve a certain amount of loss damage. If the losses are enemy the measure gauges firepower; if the losses are friendly, it gauges survivability.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate or compare firepower systems, or to compute losses for higher level measures such as time to defeat.

6. ASSOCIATED MEASURES:
- Probability of kill
- Number Losses
- Time to defeat
- Proportion of force lost
- Probability of survival

7. REFERENCES:

ACN 17419, Employment of Attack Helicopters to Defeat Armor

No ACN "Candidate MOE for Air Strike Systems", Naval Weapons Center Document # TP4687

ACN 17494, Divisional War Game Model

AVERAGE HOURLY PERCENT LOSS

1. DEFINITION OF THE MEASURE: Average hourly percent loss is the arithmetic mean of the percentage of initial force lost each hour. Input data are the initial force size and the losses each hour counted in number of personnel, weapons, tanks, aircraft or other suitable number count of force size. Relation of output to input is:

$$\text{avg hourly pct loss} = \frac{\displaystyle\sum^{n} \frac{\textbf{number of losses each hour}}{\textbf{number of initial force size}} \times 100}{\text{number of hours}}$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is a rational number in the form of an average percentage of force size.

3. LIMITS ON THE RANGE OF THE MEASURE: Losses and initial force size must be counted in the same unit, such as tanks or aircraft. If it is necessary to combine different units, the measure is more complex. Since this measure is a form of "loss rate" the answer can not be dissociated from the time period during which the counts are made. In general, the usefulness of the measure increases as the time period increases. The output is between zero and one hundred percent.

4. RATIONALE FOR THE MEASURE: The measure is a more advanced form of the "loss rate" measure taking initial force size into account. The enemy's average hourly percent loss is an indicator of friendly force firepower and the friendly average hourly percent loss is an indicator of survivability. One of the useful features of the measure is that a known average hourly percent loss can be used in conjunction with a specified percent loss breakpoint.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare systems in firepower or effectiveness, or it could be used to project a system's sustainability in the sense that a 5% average hourly percent loss implies 10 hours sustainability if 50% is the specified breakpoint.

6. ASSOCIATED MEASURES:

Loss rate	Loss exchange ratio
Casualties inflicted	Relative loss exchange ratio

7. REFERENCES:

ACN 17494, Development of a Divisional War Game Model (DIVWAG) Dec 71

EXPOSURE TIME

1. DEFINITION OF THE MEASURE: Exposure time is the total elapsed time exposed to enemy acquisition. Input data are start time of exposure and end time. Relation of output to input is the difference in the two input times:

exposure time = end of exposure timepoint - start of exposure timepoint

2. DIMENSION OF THE MEASURE: Interval -- elapsed time in seconds, minutes, or hours. If measurements are taken across time or in varying conditions, the measure may assume the form of mean exposure time or median.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may assume the value of zero or any positive measure. Exposure must be defined (is usually defined as line of sight or line of fire, but may include being within range of electronic detection) and the output can not be disassociated from the conditions defining exposure time.

4. RATIONALE FOR THE MEASURE: This measure directly addresses vulnerability or survivability. Exposure time is assumed to be the amount of time vulnerable to acquisition.

5. DECISIONAL RELEVANCE OF THE MEASURE: Exposure time is usually multiplied by probability of acquisition to determine loss in simulations. Acquisition may be intelligence acquisition or acquisition by fire. The measure is applicable whenever survivability is an important aspect of effectiveness.

6. ASSOCIATED MEASURES:
   - Time to detection
   - Time to identification
   - Time to estimate range
   - Probability of detection
   - Accuracy of identification
   - Detail of identification
   - Probability of kill
   - Loss exchange ratio
   - (Any survivability measure)

7. REFERENCES:

ACN 18171, Attack Helicopter - Daylight Defense Field Experiment

CUMULATIVE EXPOSURE TIME

1. DEFINITION OF THE MEASURE: Cumulative exposure time is the total amount of time an element is exposed to hostile fire. Input data are the elapsed times of each exposure. Relation of output to input is:

$$\text{cumulative exposure time} = \sum_{i=1}^{n} (\text{each elapsed exposure time})$$

2. DIMENSION OF THE MEASURE: Interval -- Output is a simple total of elapsed times expressed in seconds, minutes, hours, or other suitable unit of measure for chronological time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. Resolution of the measure is governed by the degree of refinement of measuring time.

4. RATIONALE FOR THE MEASURE: The amount of time exposed to enemy fire is a direct expression of susceptibility to kill, and an important component of survivability.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used in any situation where survivability is an issue. It could be used to compare competing systems on expectation of survival.

6. ASSOCIATED MEASURES:
   - Probability of survival
   - Loss rate

7. REFERENCES:

ACN M3523, Small Arms Weapons Systems (SAWS) Field Experiment 65.4 - May 66.

ACN 18171, Attack Helicopter Daylight Defense Field Experiment 43.6 - Jun 72.

ACN 16914, M60A1 Add-on Stabilization Troop Test, Apr 72.

ACN M1144, Army Aircraft Survivability Field Experiment 63.3, Jun 66.

ACN 15961, SHILLELAGH Field Experiment 11.6, Jun 69.

PROPORTION OF SURVIVORS

1. DEFINITION OF THE MEASURE: Proportion of survivors is the fraction of initial force surviving at a given time. Inputs are number count of initial force size and number count of remaining force size. Unit of measure is any suitable counting unit such as personnel, tanks, weapons or other. Relation of output to input is:

$$\text{proportion of survivors} = \frac{\text{remaining force size}}{\text{initial force size}}$$

2. DIMENSION OF THE MEASURE: Proportion -- fraction of force size surviving. Unit of measure of output is a fraction. The portion may be expressed as a fraction (31/50), decimal (.62) or percentage (62%).

3. LIMITS ON THE RANGE OF THE MEASURE: This fraction can assume values between zero and unity, inclusive. The measure can be used in any situation where survivability is a dependent variable, but the measured output is limited in applicability to a given time period under given conditions.

4. RATIONALE FOR THE MEASURE: This measure addresses survivability directly. While it does not measure the primary mission of a military unit, it addresses effectiveness indirectly in the sense that a unit must have some degree of survival to accomplish its primary mission.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used in any situation where survivability is an important issue. It would not ordinarily be useful alone, because a force could have high survivability at the cost of not accomplishing its mission.

6. ASSOCIATED MEASURES:

Loss exchange ratio
Expected remaining kill capability

7. REFERENCES:

ACN 03010, Infantry Rifle Unit Study - 75

REMAINING FORCE SIZE

1. DEFINITION OF THE MEASURE: Remaining force is the proportion of an initial force that survives at the time of measure. Input data are the size of the initial force and the size of the force at a given time. Relation of output to input is:

$$\text{Remaining force size} = \frac{\textbf{remaining number in force}}{\textbf{initial number in force}}$$

Force size is counted in number of personnel, weapons, tanks, aircraft, subordinate units, or as appropriate.

2. DIMENSION OF THE MEASURE: Ratio -- output is a proportion in terms of initial force, such as .25 or 25% of force remaining. Another form of the measure computes "expected remaining force size" as the integral with respect to time of the force size as a function of time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to unity, inclusive. It is often difficult to count force size if several different types of elements must be combined.

4. RATIONALE FOR THE MEASURE: The measure is useful in assessing the outcomes of simulated engagements. It has direct military relevance especially when used in conjunction with a specified breakpoint such as the commonly used dictum that a military force is ineffective below 70% of full strength.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually used to compare competing forces on a combination of relative firepower and survivability. It could be used directly to compare systems intended to influence survivability.

6. ASSOCIATED MEASURES: Expected remaining force size
Expected remaining tank killing capability
Proportion force surviving
Ratio of blue/red survivors

7. REFERENCES:

ACN 17494, Divisional War Game Model, Dec 71
ACN 17419, Employment of Attack Helicopters to Defeat Armor
No ACN Candidate MOE for Air Strike Systems, Naval Weapon Center Document # TP4687

PROBABILITY OF SURVIVAL

1. DEFINITION OF THE MEASURE: Probability of survival is computed as one (the probability value of certain survival) minus the product of probabilities of killing factors. Input data are the probability values of contributing killing factors. Relation of output to input is:

$$\text{probability of survival} = 1 - \left[(P_{k_1})(P_{k_2})\ldots(P_{k_n})\right]$$

Where P_{k_1} through P_{k_n} are factors such as = probable number of rounds fired, probability of single shot hit, probability of kill given a hit, and so forth.

2. DIMENSION OF THE MEASURE: Ratio -- A probability computed as unity minus the product of a set of probabilities each of which is a ratio in the sense of expressing the proportion of observed kills for attempts.

3. LIMITS ON THE RANGE OF THE MEASURE: The output depends on input of a set of mutually exclusive probabilities, each expressing the expected outcome for an independent variable but all under the same set of circumstances. The computed probability may assume any value from zero to one, but can not be dissociated from the circumstances governing the input probabilities.

4. RATIONALE FOR THE MEASURE: This is a measure of survival that takes chance variation into account, and also attempts to include all significant influencing factors. If all relevant factors are properly included, it is assumed the final resultant value represents the actual expectation of survival.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used in any circumstance in which survivability is part of effectiveness, and survivability is always a part of it in the sense that regardless of its effectiveness in performance otherwise, a system has zero effectiveness if it does not survive.

6. ASSOCIATED MEASURES:

- Probability of hit
- Probability of kill given a hit
- Attrition rate
- Probability of success
- Casualty rate
- Exposure time

7. REFERENCES:

ACN 1144V, Field Experiment 63.7 (Lethality Probabilities of Forward Area Radar Controlled Air Defense Weapons Against Army Aircraft) - Jun 67

ACN 17494, Development of a Divisional War Game Model, Dec 71.

No ACN, "Candidate MOE for Air Strike Systems," Naval Weapons Center Document #TP4687

PERSONNEL AVAILABILITY

1. DEFINITION OF THE MEASURE: Personnel availability is the percentage of either authorized or assigned personnel available. Input data are the number of personnel on hand available for duty (D), and the number of personnel either authorized or assigned (A). Relation of output to input is:

$$\text{Personnel availability} = \frac{D}{A} \times 100$$

2. DIMENSTION OF THE MEASURE: Ratio -- output is a percentage of all personnel.

3. LIMITS ON THE RANGE OF THE MEASURE: Output value may vary from zero to any positive value. It may exceed one hundred percent if based on personnel authorized. The measure has a weakness in counting each individual equally whether or not his specialty is needed.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of effectiveness of organization. It is assumed that an inappropriate value indicates difficulty in maintaining readiness due to either personnel administration or to a faulty table of organization.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate effectiveness of either a personnel administration system, or a proposed table of organization.

6. ASSOCIATED MEASURES: Operational availability
Reporting time

7. REFERENCES:

ACN 10698, Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field, Jun 67

MATERIEL

PERCENT OF TASKS SATISFIED

1. DEFINITION OF THE MEASURE: Percent of tasks satisfied is the percentage of a range of tasks satisfied by the evaluated system. The set of tasks varies in difficulty and is meant to represent the types of tasks expected. Input data are the number of tasks satisfied (T_s) and the number not satisfied (T_n). Relation of output to input is:

$$\text{percent of tasks satisfied} = \frac{T_s}{T_s + T_n} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is percentage of tasks.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to one hundred percent. The main constraint is that the set of tasks tried must be distributed in keeping with the normal expected distribution of such tasks, that is, there must be the appropriate number each of easy, intermediate and difficult tasks. Also, the criterion for satisfying a task has to be defined and the output value can not be dissociated from this definition.

4. RATIONALE FOR THE MEASURE: When the tasks properly represent the distribution of real tasks, the measure addresses effectiveness directly in terms of the amount of production expected. The measure would not ordinarily be used alone because it does not take into account differences in timeliness and accuracy.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually applied to evaluating a system in terms of the range of tasks satisfied In ACN 16495 the measure was applied to the effectiveness of vehicles in satisfying tasks of various difficulty relating to mobility, range, carrying capacity, speed, and reaction time.

6. ASSOCIATED MEASURES:

Probability of success
Time to completion
Mean error

7. REFERENCES:

ACN 16495 - Family of Army Vehicles Study

NUMBER ADDITIONAL MISSIONS CAPABLE

1. DEFINITION OF THE MEASURE: Number additional missions capable is the number count of additional missions beyond the primary mission that a system is capable of achieving. Input data are the number counts of all types of missions that can be accomplished. Relation of output to input is the number count of missions (N) minus the one primary mission:

number of additional missions capable = (N-1)

2. DIMENSION OF THE MEASURE: Interval -- output is a number of (additional) missions. If the number varies under different circumstances, the output may be in ratio form, i.e., mean number of additional missions capable.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive integer. In ratio form it may be any positive fractional number.

4. RATIONALE FOR THE MEASURE: This measure is the simplest, most direct approach to stating the flexibility of a system. It is not as refined as "probability of success" which takes into account capabilities under various missions, but it is relatively easy to measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate flexibility of a system. It may be particularly useful when systems are equivalent in most respects but one has greater flexibility.

6. ASSOCIATED MEASURES:

Probability of success
Percent tasks completed

7. REFERENCES:

ACN 17419, Employment of Attack Helicopters to Defeat Armor
No ACN, "Candidate MOE for Air Strike Systems," Naval Weapons Center document #TP 4687

PERCENTAGE DEVIATION IN PERFORMANCE

1. DEFINITION OF THE MEASURE: Percentage deviation in performance is the difference between current observed performance and previous performance. Input data are the current performance and the previous performance measured in any suitable quantitative measure of output. Relation of output to input is:

$$\text{percent deviation} = \frac{\text{previous performance minus current performance}}{\text{previous performance}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- a difference in terms of percentage of previous performance

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. The measure is constrained by the resolution of the performance measure used.

4. RATIONALE FOR THE MEASURE: The measure is intended to indicate unusual differences in performance, insituations where performance should remain relatively constant.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be applied in any situation where small deviation in performance is an issue. In ACN 16819 it was used to compare night vision systems that should yield a fairly constant level of visual aid.

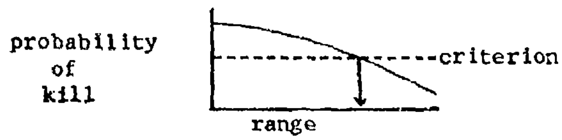
6. ASSOCIATED MEASURES:
   - Mean error
   - Standard deviation

7. REFERENCES:

ACN 16819 - STANO II Part I Troop Test, Dec 69

MAXIMUM EFFECTIVE RANGE

1. DEFINITION OF THE MEASURE: Maximum effective range is the longest distance at which a specified probability of kill is achieved. Input data are acquisition probability values as a function of range. Probability of kill may include target hits, penetration of a given target, and probability of detection. Relation of output to input is the range with respect to a given probability of kill:



2. DIMENSION OF THE MEASURE: interval -- output is in terms of range in meters, kilometers, or miles

3. LIMITS ON THE RANGE OF THE MEASURE: The criterion probability of kill counted as "effective" must be specified. Sufficient information must be available to express probability of kill as a function of range. The output can be any positive value up to the maximum range of the system.

4. RATIONALE FOR THE MEASURE: This measure addresses effectiveness of a system in one of its important aspects, range, in a manner directly applicable to decision making.

5. DECISIONAL RELEVANCE OF THE MEASURE: There are two primary uses of the measure:

a. Weapons fire. Maximum effective range of weapons fire can be measured for evaluating battle range of types of weapons.

b. Intelligence. Maximum effective range of radars, optical devices, surveillance aircraft and other intelligence systems can be evaluated or compared.

6. ASSOCIATED MEASURES:

Range of engagement — Maximum range
Range at detection — Time to Acquisition

7. REFERENCES:

ACN 06081 - Army Small Arms Weapon Systems Troop Acceptability Test

BURST RADIUS

1. DEFINITION OF THE MEASURE: Burst radius is the distance from center of burst within which there is a specified weapon effect. Input data is the specified effect which may be in terms of destruction of vehicles, killing of exposed personnel, a given concussion in terms of pounds per square inch, or other suitable expression of effect, and the observed range of the effect.

2. DIMENSION OF THE MEASURE: interval -- output is a distance in terms of inches, meters, or kilometers.

3. LIMITS ON THE RANGE OF THE MEASURE: The specified effect must be defined. If the terrain varies within the range of some effects, a convention must be established for combining differing ranges for the same effect, such as probability or mean distance. The output may assume any positive value.

4. RATIONALE FOR THE MEASURE: The measure directly addresses the destructive potential of a weapon. Once the burst radius has been determined through empirical means it can be used to compute expected effects.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually utilized in computing expected effects of nuclear weapons and artillery and mortar rounds. It could be applied to comparison of alternative firepower systems.

6. ASSOCIATED MEASURES:

   Probability of hit
   Probability of kill
   Circular error probable

7. REFERENCES:

ACN 4260 - "Personnel Risk and Casualty Criteria for Nuclear Weapons Effects", 2 Aug 71

CASUALTIES PER DOSE

1. DEFINITION OF THE MEASURE: Casualties per dose is the number of enemy casualties resulting from the delivery of a dose of chemical agent. It is the chemical warfare equivalent to casualties per round. Input data are the number of casualties inflicted and the number of doses delivered. Relation of output to input is:

$$\text{casualties per dose} = \frac{\text{number of casualties inflicted}}{\text{number of doses delivered}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is in terms of casualties per dose

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive number. It may be fractional. The number of casualties is a function of several factors other than number of doses, so the output value can not be dissociated from the conditions under which it was derived.

4. RATIONALE FOR THE MEASURE: This is a direct measure of the casualty-producing effectiveness of chemical agents. It subsumes many other factors such as range of delivery, type of delivery, accuracy and timeliness of delivery, wind and other environmental factors at the target, protective measures, size of target, and agent dissemination.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare chemical weapons systems in casualty-producing effectiveness.

6. ASSOCIATED MEASURES:
   Casualties per round
   Range at acquisition

7. REFERENCES:
   ACN 1514 - Operational Effectiveness of Vapor/Aerosol Weapons Systems

SIGNAL TO NOISE RATIO

1. DEFINITION OF THE MEASURE: Signal to noise ratio is the quotient derived from dividing the intensity of the examined signal to the sum of all other contributors to intensity. Intensity input may be in the form of decibels for noise, brightness for light, or other suitable unit of measure of intensity appropriate to the type of signal observed. Relat' n of output to input is:

$$\text{signal to noise ratio} = \frac{\text{intensity of signal}}{\text{total intensity of all other contributors}}$$

2. DIMENSION OF THE MEASURE: ratio-- a pure number expressing the ratio of a given intensity to the background intensity

3. LIMITS ON THE RANGE OF THE MEASURE: The ratio may be zero or any positive value. Typically, intensities vary so that means may be necessary in both numerator and denominator. Since intensities may change, the ratio is bonded to a given set of circumstances and the output value can not be dissociated from the conditions under which it was observed.

4. RATIONALE FOR THE MEASURE: The measure takes into account not only the intensity of the sought signal but also its contrast to competing signals.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually used in evaluating whether a system generates a signal of sufficient intensity to be discriminable from ambient signals. In ACN 18170 it was used to determine if an airborne loudspeaker could overcome natural competing noises. It can also be used to evaluate whether a display board sufficiently identifies the sought information.

6. ASSOCIATED MEASURES:
   - Probability of detection
   - Time to detection

7. REFERENCES:

ACN 18170 - ALOUD Field Experiment 42.10, Aug 71

TELEPHONE CHANNEL CAPACITY

1. DEFINITION OF THE MEASURE: Telephone channel capacity is the percentage of message demand on a telephone system that can be transmitted by the system. Input data are the number count of messages transmitted (T), the number count of messages submitted for transmission (S), and the time in hours during which these two number counts are taken (t). Relation of output to input is:

$$\text{telephone channel capacity} = \frac{\frac{T}{S} \times 100}{t}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is in the form of percentage transmitted per hour.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to one hundred percent per hour. In order for the measure to be useful, the numbers and types of message submitted must be representative of expected operational conditions.

4. RATIONALE FOR THE MEASURE: The measure addresses directly the amount of transmission that can be handled by a telephone system.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate telephone systems.

6. ASSOCIATED MEASURES:
   - Message rate
   - Message backlog

7. REFERENCES:

Communication Electronics Study 75, Phase I.

MOBILITY INDEX (WHEELED VEHICLES)

1. DEFINITION OF THE MEASURE: The mobility index for wheeled vehicles is a relative index used for comparing the ability of wheeled vehicles to traverse real estate without hinderance from obstacles, which include water barriers, steep slopes, soft soils, and dense vegetation. Input data are:

CPF = contact pressure factor (expressed as: $\frac{\text{gross vehicle wt (lb)}}{\text{tire width, (in) x rim dia., (in) x no. of tires}}$

WF = weight factor (expressed in pounds)

TF = tire factor (expressed as $\frac{\text{1.25 x tire width, in.}}{100}$)

GF = grouser factor (expressed as a factor for vehicle with or without chains).

WLF = wheel load factor $\left(\frac{\text{gross vehicle weight}}{\text{no. of wheels (single or dual)}}\right)$

CF = clearance factor $\left(\frac{\text{ground clearance, in.}}{10}\right)$

EF = engine factor (hp/ton expressed as a factor). (factors .6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison).

Relation of output to input is:

$$\text{mobility index} = .6\left\{\left[\frac{CPF \times WF}{TF \times GF} \times WLF - CF\right] \times EF \times TF\right\} - 20$$

2. DIMENSION OF THE MEASURE: Index number

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any value but is ordinarily a large positive number driven by vehicle weight in pounds. The combination of factors makes it difficult to use the index for any other purpose than comparison of vehicles.

4. RATIONALE FOR THE MEASURE: This is a combination of most vehicle characteristics significant to wheeled vehicle mobility.

5. DECISIONAL RELEVANCE OF THE MEASURE: Used to compare wheeled vehicles.

6. ASSOCIATED MEASURES: Mobility index (tracked vehicles)

7. REFERENCES:

ACN 16149, Mobility Study: Forward Area Units Vehicles

MOBILITY INDEX (TRACKED VEHICLES)

1. DEFINITION OF THE MEASURE: The mobility index for tracked vehicles is a relative index used for comparing the ability of tracked vehicles to traverse real estate without hinderance from obstacles, which include water barriers, steep slopes, soft soils, and dense vegetation. Input data are:

CPF = contact pressure factor (lbs/sq in. of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width, in./100)
GF = grouser factor (height in inches)
BF = bogie factor (gwt, lbs/10) (no. of bogies in contact with ground) x (area in sq in. per track shoe)
CF = clearance factor $\frac{\text{(ground clearance, in.)}}{10}$
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

Relation of output to input is:

$$\text{mobility index} = \left[\frac{\text{CPF} \times \text{WF}}{\text{TF} \times \text{GF}} + \text{BF} - \text{CF} \right] \times \text{EF} \times \text{TF}$$

2. DIMENSION OF THE MEASURE: Index number.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any value, but is ordinarily a large positive number driven by vehicle weight in pounds.

4. RATIONALE FOR THE MEASURE: This measure is a combination of most factors significant to tracked vehicle mobility.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is used to screen candidate tracked vehicles according to the requirements of the intended user-mission environment. The knowledge thus derived provides a basis for focusing attention on vehicle performance factors most in need of significant improvement and enabling the development of the equipment according to requirements imposed by the environment.

6. ASSOCIATED MEASURES:
Mobility index (wheeled vehicles)

7. REFERENCES:
ACN 16149, Mobility Study: Forward Area Units Vehicles

HUMAN FACTORS RATING

1. DEFINITION OF THE MEASURE: The human factors rating is a combination of judgemental ratings on both the favorable and unfavorable aspects of each quality judged. The individual qualities are rated on a zero to one scale for favorable aspects (x) and zero to one for unfavorable aspects (y). The y for the first is subtracted from the x for the first (x_1-y_1), the second (x_2-y_2) and so forth until the last considered aspect (x_n-y_n). The differences are then added and divided by the number of aspects (n) for the overall rating:

$$\text{human factors rating} = \frac{(x_1-y_1) + (x_2-y_2) + \ldots (x_n-y_n)}{n}$$

2. DIMENSION OF THE MEASURE: Ratio -- an average of the ratings of all qualities. If the qualities are not all of equal importance, each difference could be multiplied by a weight, itself a decimal fraction of unity, to yield a weighted average.

3. LIMITS ON THE RANGE OF THE MEASURE: The final measure is limited by the validity and reliability of the judgements that constitute the input. The final value is an average rating that can vary from negative one to positive one, unless weights are used that do not total to unity.

4. RATIONALE FOR THE MEASURE: This measure takes each contributing factor into account, and considers both the positive and negative aspects of each. The judgements are somewhat disciplined by the constraint for rating from zero to one. A positive overall value indicates a favorable balance of human factors, a negative shows an unfavorable balance, and zero indicates no effect from human factors.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to put human factors variables into a usable form. The referenced study used two qualities of weapons, ease of operation and sensory characteristics. Any number of factors can be used. If more than one person does the ratings, a mean average rating can be computed. A human factors rating will probably be secondary and supplementary to primary performance measures, since if human factors are significant enough they will affect primary measures.

6. ASSOCIATED MEASURES:
   (Any primary effectiveness measure)

7. REFERENCES:
   ACN 03498, Small Arms Weapons System Study

ITEM FAILURE RATE

1. DEFINITION OF THE MEASURE: Item failure rate is the number of items failing per stated unit of time. Input is a number count of failures, and elapsed time during which failures were counted. The relation between input and output is:

$$\text{failure rate} = \frac{\text{number of failures}}{\text{increment of time}}$$

2. DIMENSION OF THE MEASURE: Rate -- Unit of measure of the output is failures per stated time period.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive value. If the time period is short it may be fractional. Although the range of the measure is not limited, it is noted that its usefulness is tied to the time period stated because the failure rate may change over time. A failure rate of 30 per month may not be equivalent to one per day if failures tend to increase with time, and if the rate accelerates like this 30 per month would also not be equivalent to 360 per year. A limitation to this measure, then, is that it is applicable only to the time period stated unless the rate is a straight-line constant over time.

4. RATIONALE FOR THE MEASURE: Failure rate is an indication of the expected reliability of an item. Reliability is a component of the effectiveness of an item in the sense that regardless of degree of effectiveness when operating, an item has zero effectiveness after it has failed and the expectation of failure should be taken into account in measuring effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare items' effectiveness when reliability is part of the comparison. It was used in ACN 10698 both to compare items and to compare maintenance programs for an item. This is a measure that can seldom be used alone; it usually must be used in conjunction with associated measures of effectiveness. In a more complex form of "change in failure rate over time" it could be used in evaluating system life characteristics.

6. ASSOCIATED MEASURES:
   - Mean time between failure
   - Mean time to repair

7. REFERENCES:

ACN 10698, Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field - Jun 67.
ACN 06081, Army Small Arms Weapon Systems Troop Acceptability Test.
ACN 16818, STANO II Test.

MEAN TIME BETWEEN FAILURES

1. DEFINITION OF THE MEASURE: Mean time between failures (MTBF) is the average elapsed time between failures of a system. Input data are the number of failures and elapsed time between them. Relation of output to input is the sum of the elapsed times divided by the number of failures (n):

$$MTBF = \frac{\sum^{n} \text{(each elapsed time to next failure)}}{n}$$

2. DIMENSION OF THE MEASURE: Ratio -- a mean in terms of average time.

3. LIMITS ON THE RANGE OF THE MEASURE: Output can be any expression of chronological time in seconds, hours, days, or higher. The measure is not meaningful until there has been at least one failure and becomes more useful as the amount of total elapsed time increases.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of system effectiveness, reliability. The MTBF is used as an expected failure-free life.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare materiel systems, compute maintenance requires, or adjust other measures to take reliability into account.

6. ASSOCIATED MEASURES: Expected system life
Failure rate
Mean time to repair

7. REFERENCES:

ACN 10698, Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field, Jun 67
ACN 11585, Division Logistics Systems Test, Jul 69
ACN 06930, Troop Test Frontier Shield
ACN 06500, Maintenance Study - 75

MEAN MILES BETWEEN FAILURE

1. DEFINITION OF THE MEASURE: Mean miles between failure is the arithmetic average of number of miles traveled by a vehicle before experiencing a vehicle failure. Input is miles traveled and number of failures. Relation of output to input is:

$$\text{mean miles between failure} = \frac{\sum^{n}(\text{total miles traveled each failure})}{\text{number of failures}(n)}$$

2. DIMENSION OF THE MEASURE: Ratio -- Unit of measure of the output is miles per failure. Units of measure for the input are failures and miles. If observed over time it can be computed in the form of probability of failure or expectation of failure by taking an integral of the failures by time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output is meaningless until there is at least one failure, and becomes more meaningful as the number of failures increases. The output takes any positive value over zero. (In the probability or expectation form the highest value is unity.)

4. RATIONALE FOR THE MEASURE: This measure is a uniform measure of reliability for different vehicles which might have different values for other measures of reliability.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure allows whole vehicle systems to be compared in logistical terms for operational circumstances regardless of differences among vehicles and maintenance systems involved.

6. ASSOCIATED MOE'S:

Mean time between failure	Failure rate
Expected mean time to failure	Operational readiness

7. REFERENCES:

Risk Analysis for XM705/XM737, US Army Logistics Management Center

MISSILE PREFLIGHT RELIABILITY

1. DEFINITION OF THE MEASURE: Missile preflight reliability is the probability that the missile system will enter and complete all functions necessary for the successful launching of a missile. Input data are the reliability of the missile (Pr_M) and reliability of ground support equipment (Pr_{GSE}). Relation output to input is:

$$\text{missile preflight reliability} = (Pr_M) \times (Pr_{GSE})$$

2. DIMENSION OF THE MEASURE: ratio -- the output is essentially a probability which is basically the number of favorable outcomes divided by the number of possible outcomes. In this case two such probabilities are multiplied because they are conditional.

3. LIMITS ON THE RANGE OF THE MEASURE: The output reliability value can vary from zero to unity. The measure is the product of two probabilities each of which can vary from zero to unity. The usefulness of the measure depends in large part on the amount of data that is used to derive these two ratios.

4. RATIONALE FOR THE MEASURE: The measure addresses reliability directly in the sense that the reliability of the whole system is made of the probability of success in two subsystems.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is suitable for rating missile systems on reliability. This measure is, in effect, the probability of success for a launch.

6. ASSOCIATED MEASURES:
   - Probability of success (in missile flight)
   - Failure rate

7. REFERENCES:

(No ACN) - AMCQA - 113 System Effectiveness Status Report Pershing, 10 Feb 72

VULNERABILITY INDEX

1. <u>DEFINITION OF THE MEASURE</u>: This vulnerability index is a combination of exposure time, defensive fire, and hits. Input data are:

TH = target hits
NM = near misses
ET = exposure time
RF = rounds fired
RA = rounds available

Relation of output to input is:

$$\text{vulnerability index} = 1 - \left(\frac{4TH + NM}{ET}\right)\left(\frac{RF}{RA}\right)$$

2. <u>DIMENSION OF THE MEASURE</u>: index number -- a combination of factors intended to express vulnerability

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: The output is a fraction between zero and unity. Usefulness of the index is limited to the assumptions in its construction. For example, in this case target hits are counted as exactly four times as valuable as near misses. Other indexes may be as useful or more useful.

4. <u>RATIONALE FOR THE MEASURE</u>: The measure combines three factors that are relevant to vulnerability. Exposure time is one factor and the amount and accuracy of defensive firing are the others.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure may be used to compare alternative weapons systems. In the referenced study it was used to compare competing material systems and tactical procedures for tanks.

6. <u>ASSOCIATED MEASURES</u>:
   - Probability of survival
   - Exposure time
   - Probability of kill given a hit

7. <u>REFERENCES</u>:

ACN 16914 - M60A1 Add-On Stabilization Troop Test, Apr 72

COST EFFECTIVENESS INDEX

1. DEFINITION OF THE MEASURE: The cost effectiveness index is the ratio of incremental effectiveness divided by difference in cost. Incremental effectiveness is computed as a percentage. The four input values are candidate effectiveness, standard effectiveness, candidate cost, and standard cost. (Costs are peacetime costs.) Relation of output to input is:

$$\text{cost effectiveness index} = \frac{\dfrac{\text{candidate effectiveness} - \text{standard effectiveness}}{\text{standard effectiveness}} \times 100}{\text{candidate peacetime cost} - \text{standard peacetime cost}}$$

2. DIMENSION OF THE MEASURE: Index number -- a combination of quotients and differences in a form yielding a pure number that is a ratio of a percentage and a cost so that the output is a percentage improvement per dollar.

3. LIMITS ON THE RANGE OF THE MEASURE: There is no limit on the measure itself. It may be any positive or negative value and will ordinarily be a small fractional value of percentage per dollar. The two effectiveness inputs must be expressed in the same unit of measure, and the two cost inputs in the same unit. While the measure itself is not limited, it is noted that it is usually difficult to collect effectiveness data and cost data.

4. RATIONALE FOR THE MEASURE: This measure takes into account both performance and costs in determining the effectiveness in meeting objectives. Further, it handles both in terms of differences between the candidate and the standard so that the measure goes directly to the differences.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure was used to compare candidates with the standard in the referenced study, and was further used to rank order candidates. It can be used any time the performance effectiveness is directly measureable and costs are a relatively important part of the objective. It is less useful when costs are not an important part of the decision.

6. ASSOCIATED MEASURES:

7. REFERENCES:

ACN 07356, Tank, Antitank, Assault Weapons Systems Requirement Study - Phase III (TATAWS III)

PERFORMANCE TO COST-RATIO FIGURE OF MERIT

1. DEFINITION OF THE MEASURE: **Performance to cost-ratio figure of** merit is any measure of performance divided by the ratio of the cost of the considered candidate to the average cost of all candidates. Input data are the performance measure value and the costs of all candidates. Relation of output to input is:

$$\text{performance to cost-ratio figure of merit} = \frac{\text{performance}}{\dfrac{\text{cost of considered candidate}}{\text{average cost of all candidates}}}$$

2. DIMENSIONS OF THE MEASURE: index number -- the output is the ratio of performance to a cost indicator. (The performance measure may itself be a ratio). The output is a pure number or might be considered "performance per cost-ratio value."

3. LIMITS ON THE RANGE OF THE MEASURE: If the performance measure is positive, the figure of merit may assume any positive value limited only by the size of the difference between the candidate cost and the average cost.

4. RATIONALE FOR THE MEASURE: This measure is simply a convenient combination of performance and cost measures. Other combinations are equally viable, for example:

$$(\text{performance}) \times \frac{\text{avg cost of all candidates}}{\text{cost of considered candidate}}$$

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare candidates on both cost and performance simultaneously, especially to rank several candidates. In the referred study the performance measure was friendly/enemy force ratio.

6. ASSOCIATED MEASURES:
   - Cost ratio
   - Cost equalization point
   - Initial cost amortization figure of merit

7. REFERENCES:

No ACN- Parametric Design/Cost Effectiveness Study for a Mechanized Infantry Combat Vehicle-1970 (MICV-70), Cornell Aeronautical Laboratory Report #GM 2144-H-1a, Nov 66

COST EQUALIZATION POINT

1. <u>DEFINITION OF THE MEASURE</u>: The cost equalization point is that point in the useful life of two candidate systems at which their cumulative costs are equal and their cumulative production is equal. Production might be measured as time in service, casualties, or any measure of effectiveness. Input data are cumulative cost curves for the two systems as a function of cumulative production. Relation of input to output is the point of intersection of the two curves:

2. <u>DIMENSION OF THE MEASURE</u>: ratio --the relationship between the two costs is essentially their ratio for each value of production, with the intersection point at the ratio 1.00

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: Both cumulative cost and cumulative production are difficult data to obtain, and both may have to be projected into the future for decision. If there is no intersection point within the domain of cumulative service, there is no cost equalization point.

4. <u>RATIONALE FOR THE MEASURE</u>: The measure is based on the assumption that a system with a lower initial cost per unit of production may have a higher cumulative cost after some production has been accomplished and support and replacement costs are considered. If this does not hold, there is no cost equalization point. The graph of measures the amount of production a higher initial cost system must yield before it is competitive with a lower initial cost system.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure is used to compare two systems on cost effectiveness, taking expected system life into account.

6. <u>ASSOCIATED MEASURES</u>:
   Initial cost amortization figure of merit.

7. <u>REFERENCES</u>:
   No ACN - "A Model for Cost Effectiveness Evaluation of Counterbattery Target Acquisition Systems", Cornell Aeronautical Labortories Report #GM 2144-H-1a, Nov 56

INITIAL COST AMORTIZATION FIGURE OF MERIT

1. DEFINITION OF THE MEASURE: Initial cost amortization figure of merit is the point of intersection between cost curves for alternative systems over service life. Input data are the costs (including both initial cost and cumulative support costs) for each alternative as a function of life. Life may be expressed in number of hours service, rounds fired, chronological time, or engagements fought. Relation of output to input values is the plotted intersection of the curves:

2. DIMENSION OF THE MEASURE: ratio--although the output is a value equal to the service life at point of intersection, the measure is essentially a ratio in the sense that it could be expressed as the quotient between cost of A and cost of B at each point in life, with the 1.00 point defining the intersection.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure requires cost data that may be difficult to obtain. The point of intersection may vary from zero to any positive value, or to infinity if there is no practical intersection.

4. RATIONALE FOR THE MEASURE: The measure is based primarily on the assumption that systems with lower initial cost have higher support costs over time (including replacement) than systems with higher initial costs. When this is true, the plotted curves show a cross-over point. Below the cross-over point the cheaper system has the lower life cost and above the cross-over point the more expensive system has the lower life cost. That is, the cheaper system is better in the short run and the more expensive system is better in the long run. If there is no cross-over point the measure is trivial but still valid.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure compares systems on life cost, so that a decision can be made for any stated required life.

6. ASSOCIATED MEASURES:

Initial cost	Expected system life
Cumulative support cost	Cost equalization point

7. REFERENCES:

No ACN- "Parametric Design/Cost Effectiveness Study for a Mechanized Infantry Combat Vehicle-1970 (MICV-70), Cornell Aeronautical Laboratory Report #GM 2144-H-1A, Nov 66

TRAINING

COMPOSITE PASS/FAIL INDEX

1. DEFINITION OF THE MEASURE: The composite pass/fail index is a combination of pass or fail decisions into a higher level pass or fail decision. It may be combined at several levels, in pyramidal form leading to a grand pass/fail index at the highest level. Input data are the pass/fail decisions at the lowest level.

2. DIMENSION OF THE MEASURE: index --at the lowest level the measure is a binary one for each element, and at each higher level the combination becomes more abstract.

3. LIMITS ON THE RANGE OF THE MEASURE: The criterion for each pass or fail at the lowest level must be specified. A characteristic of the index is that a single failure at any level leads inexorably to a failure at the top. The index is thus constrained to only elements that are in fact critical pass or fail elements, or a complex compensatory scheme must be constructed.

4. RATIONALE FOR THE MEASURE: The measure has the advantage of a clear and immediately applicable output. It also delineates the point or points of failure. One of its primary advantages is that it is relatively inexpensive in the evaluation of a large system with many variables.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable in any system evaluation that is limited to a pass or fail issue. Since it does not address the degree of passing or failing it is usually only applicable in the case of accepting or rejecting a system.

6. ASSOCIATED MEASURES:
   - Probability of success
   - Probability of win

7. REFERENCES:
   - ACN 06930 - Troop Test Frontier Shield, May 66
   - ACN 17496 - Field Evaluation of the Modified ASTRO Mechanized Division

MEAN EVALUATOR RANKING

1. DEFINITION OF THE MEASURE: Mean evaluator ranking is the average of a set of rankings by a selected group of experienced personnel. Input data are the rankings assigned by each evaluator to each alternative, and the number of evaluators. The relation of output to input is:

$$\text{mean evaluator ranking} = \frac{\sum^{n} \text{(ranking by each evaluator)}}{\text{number of evaluators}}$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is an arithmetic mean of rankings.

3. LIMITS ON THE RANGE OF THE MEASURE: The output is limited to the number of ranks used by the evaluators. If the evaluators rank three candidates as first, second, and third, the mean rank for a candidate falls between one and three. A higher number of evaluators makes the mean ranking more refined, and theoretically makes it more valid. In any case, the larger the number of evaluators, the more stable the mean is, in the sense that each additional evaluator has less influence on the overall mean than each of a lesser number of evaluators.

4. RATIONALE FOR THE MEASURE: **This measure addresses effectiveness by using opinions of evaluators directly. A mean evaluator ranking is considered more valid than any single person's opinion.**

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used in any situation involving ranking of candidates. Its application is quite broad, depending only on the suitability of using a judgemental evaluation.

6. ASSOCIATED MEASURES:
   Mean estimate

7. REFERENCES:

ACN 3067, Infantry Rifle Unit Study 1970-75 (IRUS), Field Experiment 65.1 - Jul 69.
ACN 16813, ACCB I Field Test.
ACN 11585, Organization and Operation of the Division G4 Section Standardized Division G4/DISCOM Commander Relationship Worldwide.
ACN 16495, Family of Army Vehicles Study
ACN 00079, Field Evaluation of the Combat Support Hospital
ACN 06933, Explosive Ordnance Disposal in the Field Army

TIME TO COMPLETION

1. DEFINITION OF THE MEASURE: Time to completion is the elapsed time from initiation to completion of a task. Input data are the time of initiation and the time of completion. Relation of output to input is:

time to completion = completion time minus start time

2. DIMENSION OF THE MEASURE: interval--a measure of time in seconds, hours, or days as appropriate. With successive observations the measure could be in the ratio form, such as mean time to completion or expected time to completion.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The resolutions of the measure depends on the degree of refinement of designating start and end times.

4. RATIONALE FOR THE MEASURE: This measure directly addresses timeliness as a component of effectiveness. It subsumes many factors that may delay completion of a task, so that it is a higher level measure suitable togrosser evaluations.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can compare alternative systems in the timeliness aspect of effectiveness. It is quite general and can be applied to many different sorts of tasks such as tactical moves, intelligence missions, and taking of objectives.

6. ASSOCIATED MEASURES:

- Probability of success
- Time to first fire
- Time to detection
- Planning time
- Pct moves completed on time

7. REFERENCES:

ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75, 15 Aug 67

ACTUAL/POTENTIAL PRODUCTIVITY RATIO

1. DEFINITION OF THE MEASURE: Actual/potential productivity ratio is the actual amount of production as a proportion of the potential production. Potential production is defined as the maximum possible production. Input data are any measure of actual production and any measure of potential production, both in precisely the same unit of measure.

$$\text{actual/potential productivity ratio} = \frac{\text{actual production}}{\text{maximum potential output}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a pure number expressing actual productivity as a fraction of potential. The numerator and denominator may be ratio's or complex indexes, but are expressed in exactly the same form so that all referents cancel, leaving a pure number.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive value up to unity. The main disadvantage to this measure is that maximum productivity is sometimes difficult to compute. The maximum productivity of a firing battery could be computed by multiplying the number of tubes by the firing rate for the maximum rounds per minute, but the maximum theoretic production of a command and control system such as a unit staff is more difficult to handle. Also, there are cases in which the maximum production is easy to state but is not altogether relevant, such as the percent casualties returned to duty.

4. RATIONALE FOR THE MEASURE: This measure is probably the most direct measure of effectiveness available. When the maximum possible productivity can be stated meaningfully and actual production can be observed in precisely the same units, this measure is usually the best MOE.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable in any situation where the two input values can be obtained. Applications are: proportion targets detected, proportion moves completed by time ordered, proportion enemy force destroyed, proportion engagements won, proportion transmissions complete, percent supply requests met, and operational availability.

6. ASSOCIATED MEASURES:
   (All proportion, percent, and probability measures)

7. REFERENCES:
   None, this is a potential proposed measure

SLOPE OF LEARNING CURVE

1. DEFINITION OF THE MEASURE: The slope of the learning curve is the numerical expression of the rate of improvement in performance at a given point in training. The input data is performance level at two or more points in training. (If training is constant, the points in training are equivalent to points in time.) The relation of output to input is:

$$\text{slope of learning curve} = \frac{\text{incremental gain in performance level}}{\text{incremental added training (or incremental time)}}$$

2. DIMENSION OF THE MEASURE: Rate of learning -- Unit of measure of output is in terms of gain in performance per additional block of training (or per time period).

3. LIMITS ON THE RANGE OF THE MEASURE: The rate can vary from zero upward, and is constrained on the high side only by the degree of performance that constitutes perfection. The amount of training given must be measured in at least two increments, and improves in usefulness when measured in smaller increments. (In addition, the measure would be meaningless if full performance is attained without any training.)

4. RATIONALE FOR THE MEASURE: A characteristic learning curve has been observed in most military training situations. In general, performance improves rapidly early in training when everything learned adds to performance but improves less and less rapidly as performance approaches perfection and improvement is difficult. Assuming this relationship to hold, the slope of the learing curve is a measure of state of training. A zero rate means fully trained; a slight slope means nearly fully trained; a steep slope indicates early stage of training.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in the situation where a unit is training under a new system, with developmental equipment or with a trial organization. In this situation it may be easy to measure performance but difficult to say what proficient unit performance is. In general, the MOE is to determine whether a military unit is still early in training or has nearly reached the highest level it will attain.

6. ASSOCIATED MOE'S:
Unit proficiency

7. REFERENCES:
None, this is a proposed potential MOE not previously applied.

CIRCULAR MISS DISTANCE

1. DEFINITION OF THE MEASURE: Circular miss distance is the straight line distance from the observed point to the true center of target. Input data are the distances north-south and east-west of true center, and angle of the straight line distance. Relation of input to output is:

$$\text{circular miss distance} = \sqrt{\text{square of north-south distance} + \text{square of east-west distance}}$$

$$\text{or alternatively} = \frac{\text{north distance}}{\text{cosine of angle from observed point to true center}}$$

(when $\cos\theta \neq 0$)

2. DIMENSION OF THE MEASURE: Interval -- output is a distance in terms of inches, meters, kilometers, or miles. The measure could be in ratio form such as "mean circular miss distance" or "mean spherical miss distance (taking north-south, east-west, and altitude into account)".

3. LIMITS ON THE RANGE OF THE MEASURE: The measure can assume any positive value. It requires a grid, such as map grid, for coordinates. Resolution of the measure depends on the refinement of the grid used.

4. RATIONALE FOR THE MEASURE: This measure directly addresses accuracy of location.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is ordinarily used to evaluate accuracy of position location or delivery of fire.

6. ASSOCIATED MEASURES: Mean error
Mean offset error
Circular error probable
Standard deviation

7. REFERENCES:

ACN 17781, Precision Position Locater System Field Experiment 42.9, Jun 71

PERCENT PERSONNEL INFORMED

1. DEFINITION OF THE MEASURE: Percent personnel informed is the percentage of a unit's personnel that are aware of a selected item of information that should be known to all. The information can be password/countersign, current mission, location of prisoner compound, or any other item of information that is intended to be fully disseminated. Input data are the number of troops questioned in the survey and the number aware of the information. Relation of output to input is:

$$\text{percent personnel informed} = \frac{\text{number personnel aware of item}}{\text{number personnel asked}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is a percentage

3. LIMITS ON THE RANGE OF THE MEASURE: Output can vary from zero to one humdred per cent. Since the output is a percentage of a sample of all personnel, the value is an estimate of the percent informed of the whole unit, and the sample must be large enough to ensure acceptable confidence that it represents the whole unit.

4. RATIONALE FOR THE MEASURE: The message addresses effectiveness of the command, control and communications system. It addresses the efficiency of disseminating needed information which is considered a function both of the command and control system currently and as an end result of training.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to assess level of training in regard to command, control, and communications.

6. ASSOCIATED MEASURES:

Reporting time
Time to disseminate

7. REFERENCES:

No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PERCENT POSITIONS AUTHORIZED MOS

1. DEFINITION OF THE MEASURE: Percent positions authorized MOS is the percentage of actual organization positions in a unit that are currently occupied by personnel with the military occupational specialty authorized for that position. Input data are the number of positions and the number of these positions so occupied. Relation of output to input is:

$$\text{percent positions authorized MOS} = \frac{\text{number positions}}{\text{nr with authorized MOS assigned}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of positions.

3. LIMITS ON THE RANGE OF THE MEASURE: Output could vary from zero to one hundred percent. As defined this measure has a weakness because it ignores empty positions. It might be more useful as "percent authorized TOE positions with authorized MOS".

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of organization indirectly by examining success in assigning to positions. It is based on the theorem that if the organization is faulty personnel will be assigned other than as organized.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure was intended to evaluate a proposed organization. It was used differently, however, in the referenced study. In that project it was used as an indirect assessment of probable state of training.

6. ASSOCIATED MEASURES: Proportion authorized strength assigned
Slope of learning curve

7. REFERENCES:

No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PERCENT EEI MET

1. DEFINITION OF THE MEASURE: Percent EEI met is the percentage of planned essential elements of information that are satisfied during an operation. Input data are the number of EEI included in the intelligence plan and the number of those satisfied. Relation of output to input is:

$$\text{percent EEI met} = \frac{\text{number EEI satisfied}}{\text{number EEI planned}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of EEI.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may vary fron zero to 100%. The criterion for satisfying an EEI must be defined.

4. RATIONALE FOR THE MEASURE: The measure addresses intelligence **effectiveness** in the sense of how well the intelligence system performs in meeting its own goals for essential information.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate an intelligence system. It might be applied to a comparison of intelligence procedures, trial of collection means, or test of training.

6. ASSOCIATED MEASURES:

Percent targets acquired	Time to acquisition
Probability of detection	Time to detection

7. REFERENCES:
None - this is a potential measure.

PERCENT ENEMY DOCUMENTS TIMELY EVACUATION

1. DEFINITION OF THE MEASURE: Percent enemy documents time evacuation is the percentage of all captured enemy documents that are either, one, delivered to the interrogation site prior to or coincident with the delivery of associated prisoners, or two, delivered to G2 prior to start of any action stated in the documents. Input data are the times stated, and relation of output to input is:

$$\text{Percent enemy documents timely evacuation} = \frac{\text{number documents on time}}{\text{number documents captured}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of documents.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to one hundred percent. It may be difficult to define the criterion time in some cases. The measure is somewhat diluted by the inclusion of documents that are neither associated with prisoners nor contain information associated with any timed actions, because these documents are by definition always on time.

4. RATIONALE FOR THE MEASURE: The measure is intended to address effectiveness of one aspect of an intelligence system, the timeliness of evacuating documents.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure was used to assess intelligence training of a unit.

6. ASSOCIATED MEASURES: Evacuation time (enemy materiel). Evacuation time (prisoners).

7. REFERENCES: No ACN, Reserve Components Revised ATT, USCONARC, Mar 72.

ENEMY MATERIAL EVACUATION TIME

1. DEFINITION OF THE MEASURE: Enemy material evacuation time is the elapsed time from capture of an item of enemy material with intelligence value to the techical intelligence element designated by the G2. Input data are the time of capture and the arrival time at the technical intelligence site. Relation of output to input is:

enemy material evacuation = time material arrives at designated technical intelligence point minus time of capture

2. DIMENSION OF THE MEASURE: interval -- elapsed time in minutes, hours, and days. If several observations are made, the measure may be in ratio form such as mean evacuation time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. The absolute time interval is usually not meaningful in itself and can not be dissociated from the type of material involved and the tactical circumstances.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of effectiveness in intelligence collection.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually applied to an evaluation of intelligence functioning.

6. ASSOCIATED MEASURES:
- Mean time to report intelligence
- Mean intelligence document evacuation time
- Mean time to evacuate prisoners

7. REFERENCES:

ACN 00004 - A Method for Integration of Medical Accounting Reporting Supply and Regulating of the Army in the Field into ADSAF - CS_3 Program

PERCENT PLATOON LEADERS WITH MAP OF AO

1. DEFINITION OF THE MEASURE: Percent platoon leaders with map of AO is the percentage of all platoon leaders in an organization who have been issued a map of the area of operations. Input data are the number of platoon leaders and the number of those who have a map of the AO. Relation of output to input is:

$$\text{Percent platoon leaders with map of AO} = \frac{\text{number with map}}{\text{number platoon leaders}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of platoon leaders. If the measure is taken over time, it might be used in the form "average percentage of platoon leaders with map of AO".

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. The measure is limited somewhat by being confined to just one level of leadership, and is somewhat unrefined in treating all platoon leaders as of equal need.

4. RATIONALE FOR THE MEASURE: The measure directly addresses one aspect of effectiveness of an intelligence system, the dissemination of relevant maps.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate one aspect of an intelligence system. It would most likely be applicable to measuring training level.

6. ASSOCIATED MEASURES: Dissemination time.

7. REFERENCES: No ACN, Reserve Components Revised ATT, USCONARC, Mar 72.

PERCENT TRANSMISSIONS WITH VIOLATIONS

1. DEFINITION OF THE MEASURE: Percent transmissions with violations is the percentage of all communication transmissions by a unit with either procedural or security violations, or both. Input data are the number of transmissions and the number of transmissions with errors. Relation of output to input is:

$$\text{percent transmissions with violations} = \frac{\textbf{number of transmissions with errors}}{\textbf{number of transmissions}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio-- output is a percentage of total transmissions

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. The measure has two weaknesses: (1) It does not take into account differences in seriousness of violation, and (2) it does not take into account more than one violation per transmission.

4. RATIONALE FOR THE MEASURE: This measure addresses state of training concerning communications. It is an indicator of how well a units' personnel can observe significant communications and security rules.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to assess training level.

6. ASSOCIATED MEASURES:
   Percent transmissions completed
   Message rate

7. REFERENCES:
   No ACN - Reserve Components Revised ATT, USCONARC, Mar 72

TIME TO ESTIMATE RANGE

1. DEFINITION OF THE MEASURE: Time to estimate range is the elapsed time from detection of a target to estimation of range. Input data are the moment of detection and the moment estimation of range is complete. Relation of output to input is:

time to estimate range = time of estimation - time of detection

2. DIMENSION OF THE MEASURE: Interval -- elapsed time in terms of seconds. If the measure is taken at different times or under varying circumstances, it can be used in the form of mean time to estimate range or median time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be zero or any positive value. The resolution of the measure is limited by the precision of taking start time and end time. The data cannot be disassociated from the definition of competed estimation used, whether it is the first estimate stated regardless of accuracy or is the final in a series of estimates which is used for firing.

4. RATIONALE FOR THE MEASURE: This measure addresses a component of target acquisition time. Problems in estimation are assumed to contribute to the length of estimation time.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure can be used to compare estimation times of means of range estimation (techniques, aids, rangefinders, trained personnel) to each other or to a standard. It would not ordinarily be used alone, but would be combined with accuracy of estimation or accuracy of firing in most cases.

6. ASSOCIATED MEASURES:
   - Accuracy of range estimation
   - Firing accuracy
   - Time to detect
   - Exposure time
   - Time to identify
   - Probability of hit
   - Probability of kill

7. REFERENCES:

ACN 18171, Attack Helicopter - Daylight Defense Field Experiment

TRANSCRIPTION SPEED

1. DEFINITION OF THE MEASURE: Transcription speed is the rate at which a court reporter transcribes verbatim court pro eedings into an authenicated court record. Input data are the number of words transscribed and the number of minutes elapsed in transcription. Relation of output to input is:

$$\text{transcription speed} = \frac{\textbf{number of words transcribed}}{\textbf{number of minutes elapsed}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is a rate, words per minute

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. A convention must be established for the effect of errors on the measure.

4. RATIONALE FOR THE MEASURE: This measure is the single relevant measure of effectiveness for court reporters.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to determine the number of court reporters needed.

6. ASSOCIATED MEASURES:
   None

7. REFERENCES:
   ACN 13114, Court Reporting Systems Study, Sep 70

LOGISTICS

AMMUNITION EXPENDITURE RATE

1. DEFINITION OF THE MEASURE: Ammunition expenditure rate is the amount of ammo used in a given observed time. Unit of measure of input is rounds (or tons, or DOA), and days (or hours, or seconds). Relation of output to input is:

$$\text{ammunition expenditure rate} = \frac{\text{amount of ammo fired (rounds, tons, DOA)}}{\text{elapsed time (days, hours, seconds)}}$$

2. DIMENSION OF THE MEASURE: Ratio -- rate of expenditure. Unit of measure of output is DOA per day, tons per hour, rounds per second, etc.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The measure is meaningless until the first round is fired, and becomes more useful as the time period increases. Since the rate may change, the measure cannot be disassociated from the time period of the observation.

4. RATIONALE FOR THE MEASURE: This measure indirectly addresses sustainability and cost. It is often used because it is an easy measure to take in models, simulations, or field work, and can be combined with costs of ammunition or capability of resupply to make useful decisions.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is rarely of use by itself. It would ordinarily be used with other measures as part of a more complex measure of effectiveness. It could, however, be used by itself to distinguish among competing candidates equal in other respects.

6. ASSOCIATED MEASURES:
   - Required ammunition resupply rate
   - Resupply capability
   - (Any measure of firepower potential)

7. REFERENCES:
   - ACN 03498, Small Arms Weapons System Study

REQUIRED AMMUNITION RESUPPLY RATE

1. DEFINITION OF THE MEASURE: Required ammunition resupply is the rate of ammunition need. Input is rounds required per day. Unit of measure of input is rounds, or alternatively tons or DOA. (Day of Ammunition -- a specified number of rounds for a type weapon.) Relation of output to input is:

$$\text{required ammo resupply} = \frac{\text{total number of rounds required (or tons, or DOA)}}{\text{number of days in time period observed}}$$

2. DIMENSION OF THE MEASURE: Ratio -- a rate in terms of rounds per day or tons per day. Unit of measure of output is rounds (or tons). In its most esoteric form it is the ratio between a predetermined "day of ammunition" which is meant to be the amount of ammunition required per day and the actual ammo per day. In this form it is "DOA per day."

3. LIMITS ON THE RANGE OF THE MEASURE: The measure must include at least one day's observation, and as the denominator gets larger the measure gets better. The output may assume any positive value. The measure is limited to a single type of round in the form "rounds per day." In the form of weight per day, it is more encompassing. For complete inclusion of different types of ammunition it is usually necessary to use the form "DOA per day."

4. RATIONALE FOR THE MEASURE: This measure addresses sustainability. It is reasoned that a good performance in other respects may be offset somewhat by difficulty in sustainability. If sustainability were difficult enough, it would affect performance and could be measured otherwise. This measure is meant to be sensitive enough to address sustainability before it is serious enough to affect performance of the mission.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure could be used to distinguish between firepower systems that are equal in productivity. Or it could be used as a further refinement in a more complete description of successful systems.

6. ASSOCIATED MEASURES:
   - Resupply frequency
   - Ammunition expenditure

7. REFERENCES:
   - ACN 03498, Small Arms Weapons System Study

TOTAL THEATER INVENTORY

1. DEFINITION OF THE MEASURE: Total theater inventory is the sum of supplies in safety stock, operating level, and interruption stock in a theater of operations. Input data are:

I_s = safety stock in tons
I_o = operating level stock in tons
I_i = interruption stock in tons

Relation of output to input is the sum:

$$\text{total theater inventory} = I_s + I_o + I_i$$

2. DIMENSION OF THE MEASURE: Interval -- Output is a number of tons.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The measure is limited in treating all supplies by weight as a common denominator, overlooking differences in importance by weight.

4. RATIONALE FOR THE MEASURE: The measure directly addresses amount of inventory.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate supply and transportation effectiveness at the theatre level.

6. ASSOCIATED MEASURES:
Total deployed inventory.

7. REFERENCES:
ACN 06841, Army Logistic Support Concept - Air Lines of Communication.

PROPORTION INVENTORY DEPLOYED

1. DEFINITION OF THE MEASURE: Proportion inventory deployed is the proportion of all supplies in inventory that have been distributed to the operating level. Input data are: the total amount of supplies (S_t), the amount designated as operating level (S_o), the amount in safety stock (S_s), and amount in interruption stock (transit, storage, or handling). All are measured in a common denominator such as tons, rounds, or gallons. Relation of output to input is:

$$\text{proportion of inventory deployed} = \frac{S_o+S_s}{S_t} \quad \text{or} \quad \frac{S_o+S_s}{S_o+S_s+S_i}$$

2. DIMENSION OF THE MEASURE: Ratio -- A proportion in terms of a decimal fraction.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be any value from zero to unity. All inputs must be expressed in the same unit of measure and it must be a unit suitable for the echelon and type of supplies. Such as tons of class IV at theatre, or number of rations at company.

4. RATIONALE FOR THE MEASURE: In theory a perfect supply system would have 100% of inventory deployed. If it were possible supplies would be replaced at precisely the rate used precluding the expense and vulnerability of storage sites. This measure determines how closely a supply system approaches the ideal.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate the effectiveness of a supply system in terms of avoiding an inventory build up. The measure can not be used alone since the best score could be obtained by simple undersupply; it must be used in conjunction with proportion of supply requirements met.

6. ASSOCIATED MEASURES:
   - Total theater inventory
   - Days of supply on hand
   - Proportion supply requirements met
   - Time to resupply

7. REFERENCES:
   None, this is a potential measure.

SUPPLY THROUGHPUT EFFECTIVENESS

1. DEFINITION OF THE MEASURE: Supply throughput effectiveness is the amount of cargo handling saved, as a proportion of the greatest possible amount of savings. Input data are:

c = cargo, in tons or other suitable unit of measure
n = number of **possible** handling points
h_i = cargo handled at point i (tons, or other unit)

Relation of output to input is tons-handling saved divided by maximum possible tons-handling saved:

$$\text{supply through effectiveness} = \frac{cn - \sum_{i=1}^{n} (h_1 + h_2 + \ldots h_n)}{c(n-2)}$$

2. DIMENSION OF THE MEASURE: Ratio -- the output is a pure number expressing the ratio between actual tons-handling saved and maximum possible tons-handling saved.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any value from zero to unity. It is necessary to treat cargo in a common unit of measure, such as tons or cubic feet, and treat the savings in tons-handling or cubic feet-handling.

4. RATIONALE FOR THE MEASURE: The measure is tons-handling saved as a proportion of the maximum possible tons-handling saved. Maximum possible tons-handling is cn and minimum is handling at first and last points only, 2c, so maximum possible savings is cn - 2c or c(n - 2). Actual savings is the total possible handling, cn, mimus actual handling, the sum of tons-handling at each point, $\sum_{i=1}^{n} (h_1 + h_2 \ldots h_n)$.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure allows supply systems to be evaluated in terms of throughput effectiveness. This measure can be combined with other supply effectiveness measures for overall measures of supply effectiveness.

6. ASSOCIATED MEASURES:
   - Proportion of supply requirements met
   - Time to resupply
   - Proportion of stock in inventory

7. REFERENCES:

ACN 06534, Transportation Service Study, TASTA-70 - Jan 67

LOT ESTIMATE PERCENT DEFECTIVE

1. DEFINITION OF THE MEASURE: Lot estimate percent defective is a measure of the proportion of defective units in a lot of Class I supply (rations). The input data are the size of the lot (N), the size of a sample drawn randomly from the lot (n), and the number of defectives in the sample (d). Relation of output to input is:

$$\text{lot estimate percent defective} = \left(\frac{d}{n}\right) N \times 100$$

2. **DIMENSION OF THE MEASURE: Ratio output is the percentage of defective units of rations in the lot.**

3. LIMITS ON THE RANGE OF THE MEASURE: A pe centage may vary from zero to one hundred per cent. This measure is subject to the amount of error that can rise from statistical sampling.

4. RATIONALE FOR THE MEASURE: The measure is based on the rationale that if a sample is drawn randomly from the whole lot, the percentage of defectives in the sample is likely to be the percentage of defectives in the lot.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is basically intended to lead to a decision on whether or not the lot is acceptable. It may be used as an evaluative indicator of a Class I supply system at higher echelons.

6. ASSOCIATED MEASURES:
   - Percent supply requests met
   - Percent supply requirements filled

7. REFERENCES:
   - ACN 00008, Inspection of Operational Rations

CARGO HANDLING RATE

1. DEFINITION OF THE MEASURE: Cargo handling rate is the amount of cargo that is loaded, transported, or unloaded in a specified time period. The amount of cargo is counted in tons, cubic feet, or other appropriate measure of bulk. Time is counted in minutes, hours, or days as appropriate. Relation of output to input is:

$$\text{cargo handling rate} = \frac{\text{amount of cargo handled}}{\text{number of time intervals}}$$

Alternatively, if the amount of cargo moved is expressed as a function of time, the rate could be computed as the first derivitive.

2. DIMENSION OF THE MEASURE: Ratio -- the output is a ratio in terms of cartons per minute, tons per hour, tons per day, or other suitable expression. Other possible ratio forms are "mean cargo handling rate" or "average percentage handling rate".

3. LIMITS ON THE RANGE OF THE MEASURE: The resolution of the measure depends on the size of the time intervals; minutes are more refined than hours. The usefulness of the measure increases as the time period increases. Since the rate may change, the output value cannot be dissociated from the time period observed. The output may be zero or any positive number.

4. RATIONALE FOR THE MEASURE: This measure addresses the timeliness of cargo handling directly. This is a factor in the larger logistical measure of turnaround time. The measure subsumes several difficulties in handling which may be expected to influence the amount of time required.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare cargo handling systems.

6. ASSOCIATED MEASURES: Turnaround time
Payload capacity
Percent supply requests met

7. REFERENCES:

Article: "Some Aspects of a Comparison of Shipboard Cranes and Burtoning Gear in Service", Publication #592, Recent Research in Maritime Transportation, National Academy of Sciences.

REDUCTION IN CUBE REQUIRING TRANSPORT

1. DEFINITION OF THE MEASURE: Reduction in cube requiring transport is the proportional change in volume of payload awaiting delivery. Input data are the volume (in cubic feet or meters) of payload at two observed timepoints (C_1, C_2) and the interval between timepoints. Relation of output to input is:

$$\text{reduction in cube requiring transport} = \frac{\frac{C_2 - C_1}{C_1}}{\text{elapsed time}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is in terms of proportional reduction per time period, such as .25 reduction per day.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to unity. The resolution of the measure depends in part on the precision of time measurement. The usefulness of the measure improves as the elapsed time lengthens, but the measure cannot be dissociated from the specified time interval because the rate of reduction may change.

4. RATIONALE FOR THE MEASURE: The measure addresses the effectiveness of a transport system in the sense that rapid reduction of backlog is an indicator of success in transport.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate transport systems.

6. ASSOCIATED MEASURES:
   - Cargo handling rate
   - Time to resupply
   - Supply throughput effectiveness
   - Payload rate

7. REFERENCES:

ACN 02330, Subsistence and Food Service for the Army in the Field

DIMENSIONAL CARRYING CAPACITY OF CARGO BED

1. DEFINITION OF THE MEASURE: Dimensional carrying capacity of cargo bed is the cubic payload carrying capacity of a tactical transport vehicle. Input data are the height (H), length (L), and width (W) of the bed. Relation of output to input is:

dimensional carrying capacity = H x L x W

2. DIMENSION OF THE MEASURE: Interval -- Output is in terms of cubic meters, feet, or inches.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be any positive number. The output actually represents a maximum capacity not taking into account unused space because of the weight or shape of the payload.

4. RATIONALE FOR THE MEASURE: The measure is an indicator of the transport effectiveness of a vehicle, or a transport unit.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare transport systems on dimensional capacity, or used in a computation of expected number of vehicles or runs required.

6. ASSOCIATED MEASURES:
   - Meantime to resupply
   - Mean payload

7. REFERENCES:
   ACN 16494, Family of Army Vehicles Study

PERCENT CARGO UNITIZATION

1. DEFINITION OF THE MEASURE: Percent cargo unitization is the percentage of cargo by volume or weight that is unitized. Unitized is defined as packed on pallets or containerized. Input data are the total volume or weight of cargo handled (T) and the same measure of total cargo unitized (U). Relation of output to input is:

$$\text{percent cargo unitization} = \frac{U}{T} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of total cargo

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. A difficulty in applying the measure is the necessity of measuring different categories of cargo in a common unit such as tons or cubic feet or meters.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of cargo handling effectiveness. In this respect, it is subordinate to higher level cargo handling measures concerning amount and timeliness of transport.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to determine whether ineffectiveness in a transport system in a higher measure is due to lack of unitization.

6. ASSOCIATED MEASURES:

- Proportion of supply requirements met
- Percent supply requests filled
- Time to resupply
- Resupply rate

7. REFERENCES:

ACN 06534 - Transportation Service Study, TASTA - 70, Jan 67

NUMBER TRANSPORT AIRCRAFT REQUIRED

1. DEFINITION OF THE MEASURE: Number aircraft required is the number of aircraft required to perform a specific transport task. Input data are:

L = amount of load to be transported (tons or number passengers)
T = round trip flying time (hours)
AL = allowable load per aircraft (tons or passengers)
U = utilization rate (hours per aircraft)
A = allowable time to complete transport task (hours)

$$\text{number transport aircraft required} = \frac{L \times T}{(AL \times U) \times A}$$

2. DIMENSION OF THE MEASURE: interval -- output is in terms of number of aircraft

3. LIMITS ON THE RANGE OF THE MEASURE: Output may vary from one to any positive integer. If different aircraft with different allowable loads are used, the terms AL and U must be expanded to express allowable utilization.

4. RATIONALE FOR THE MEASURE: The measure indicates productivity of a transport aircraft system.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare effectiveness of alernate air transport systems, or perhaps to select the optimum aircraft type for a task.

6. ASSOCIATED MEASURES:
Time to completion

7. REFERENCES:
No ACN - "Mobility System Planning Compendium", Oct 68

AIRCRAFT CAPABILITY INDEX

1. DEFINITION OF THE MEASURE: Aircraft capability index is an index number of amount of aircraft productivity by time. Input data are:

- N = number aircraft used
- U = utilization rate (hour per day aircraft used)
- A = number of days
- L = allowable payload
- T = round trip flying time

Relation of output to input is:

$$\text{aircraft capability index} = \frac{N \times U \times A \times L}{T}$$

2. DIMENSIONS OF THE MEASURE: index number-- output is a pure number expressing capability

3. LIMITS ON THE RANGE OF THE MEASURE: Input values must be in like units, such as all loads in tons, all times in days and hours. The output can be zero or any positive number. The output is meaningful if none of the terms in the numerator are zero, and becomes more meaningful as the values are higher.

4. RATIONALE FOR THE MEASURE: The index number combines several relevant factors of aircraft capability into a convenient index number. Other combinations of the same factors might be useful.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare systems involving several aircraft in terms of load-carrying capability.

6. ASSOCIATED MEASURES:
   - Tons per day
   - Cargo handling rate
   - Sortie rate
   - Aircraft payload

7. REFERENCES:
   none -- this is a potential measure.

OPERATIONAL READINESS

1. DEFINITION OF THE MEASURE: Also called "OPERATIONAL AVAILABILITY". Operational readiness or availability is the number of ready vehicles, aircraft, weapons, or other unit of measure available for operations divided by the total number in the organization or fleet, multiplied by 100. Relation of output to input is:

$$\text{operational readiness} = \frac{\text{number available for operations}}{\text{number assigned}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- proportion of items assigned that are ready, multiplied by 100 to ensure two significant digits to the left of the decimal.

3. LIMITS ON THE RANGE OF THE MEASURE: Both the numerator and the denominator must be counted in the same unit of measure. Output takes any value from zero to one hundred. Larger values of the denominator give more refinement to the measure. The m asure refers to a given moment in time, but if successive measures are taken over time, the MOE may be referred to as "expected operational readiness."

4. RATIONALE FOR THE MEASURE: This measure addresses readiness directly, which is considered a significant component of capability or potential.

5. DECISIONAL RELEVANCE OF THE MEASURE: The output can be compared to 100% readiness or to a standard for decisions involving problems in capability. Or outputs of different units can be compared directly for measures of combat service support systems or logistical systems.

6. ASSOCIATED MEASURES:
   - Reliability
   - Failure rate

7. REFERENCES:

ACN 10698, Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field (Jun 67)

MAINTENANCE FLOAT ITEM AVAILABILITY

1. DEFINITION OF THE MEASURE: Maintenance float item availability is the proportion of number of items authorized in a maintenance float that are available. Input data are the number authorized and number available. Relation of output to input is the quotient, multiplied by 100 to ensure significant digits to the left of the decimal:

$$\text{maintenance float item availability} = \frac{\text{number available}}{\text{number authorized}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a number indicating a proportion.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to one hundred. The measure is more difficult to apply when items of different types must be aggregated.

4. RATIONALE FOR THE MEASURE: The measure is an indicator of how nearly fully stocked the maintenance float is kept.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate effectiveness in keeping the float resupplied. It must be noted that it is not a measure of effectiveness of maintenance because the most ideal maintenance system would always have exactly zero maintenance float items.

6. ASSOCIATED MEASURES:
   - Mean time to repair
   - Mean time to restore to service
   - Percent maintenance requests met
   - Operational availability

7. REFERENCES:

ACN 10698, "Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field" Jun 67

MEDICAL DEMAND TRANSACTION PROCESSING TIME

1. DEFINITION OF THE MEASURE: Medical demand transaction processing time is the elapsed time required to communicate and process demand transactions between nodal points in COMMZ and Field Army. Input data are the start time and completion time. Relation of output to input is the subtracted difference:

processing time = (completion time) − (start time)

2. DIMENSION OF THE MEASURE: Interval -- An elapsed time in hours. Alternately the measure could be takn as a ratio measure, such as "mean medical demand transaction processing time."

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may assume any positive value. (The current system takes 728 to 1400 hours.)

4. RATIONALE FOR THE MEASURE: This measure addresses the timeliness aspect of one factor in medical resupply.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate proposed improvements in the medical resupply system.

6. ASSOCIATED MEASURES:

Reporting time
Time to resupply

7. REFERENCES:

ACN 00004, A Method for Integration of Medical Accounting, Reporting, Supply and Regulating of the Army in the Field into $ADSAF\text{-}CS_3$ Program.

HOSPITAL EFFICIENCY INDEX

1. DEFINITION OF THE MEASURE: Hospital efficiency index is a combination of utilization factors expressed as a Measure of Effectiveness Index. This index is directly proportional to the number of personnel assigned and the percent of beds occupied and inversely proportional to patient working time. Input data are:

P_b = the percent of beds occupied within the medical facility 0% to 100%.

E_i = the optimal utilization of critical MOS within the medical facility (60%).

A_i = the actual utilization of the critical MOS within the medical facility.

w = the average patient waiting time.

n = number of MOS's

Relation of output to input is:

$$\text{hospital efficiency index} = \frac{P_b \left(1 - \sum^{n} (E_i - A_i)\right)}{w}$$

2. DIMENSION OF THE MEASURE: index number -- combination of relevant factors

3. LIMITS ON THE RANGE OF THE MEASURE: The index can assume any positive value.

4. RATIONALE FOR THE MEASURE: This index provides an expression for computing the efficiency of operation of a given medical facility in terms of the utilization of available facilities, personnel, and patient waiting time.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used as the criterion for determining how the use of hospital resources (personnel and equipment) can be improved.

6. ASSOCIATED MEASURES:

Hospital flexibility index

7. REFERENCES:

Evaluation of Final Report, Field Evaluation, Combat Support Hospital (TOE 8-123), Medical Service Agency

HOSPITAL FLEXIBILITY INDEX

1. DEFINITION OF THE MEASURE: The hospital flexibility index is a combination of capacity, requirements and capability expressed as a Measure of Effectiveness Index. This index is defined as the ability of the hospital to react effectively to any enemy threat or attack with appropriate and adaptable actions under existing circumstances. Input data are:

- D = the total number of admissions during the period of operation of the medical facility.
- C = the total available capacity of the hospital consistent with the type category of unit.
- P_b = the percentage of bed occupancy in the hospital, 0% to 100%.
- E_i = the optimal utilization of the critical MOS personnel in each patient care area of the hospital (.60)
- A_i = the observed utilization of critical MOS personnel in each patient care area of the hospital (.0 to .60)

Relation of output to input is:

$$\text{hospital flexibility index} = 1 - \left\{ \frac{D}{C} \left[1 - \sum_{i=1}^{n} (E_i - A_i) \right] P_b \right\}$$

2. DIMENSIONS OF THE MEASURE: index number -- combination of relevant factors

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value, but will be a fraction between zero and one unless admissions greatly exceed capacity.

4. RATIONALE FOR THE MEASURE: This index is used to compute the flexibility index of a given support hospital. For a given size medical facility with a stated evacuation policy and stated medical workload, the degree of flexibility can be determined. It provides the planner/manager with an accurate means of determining the desired efficiency rate and flexibility rate based on daily medical workload and evacuation policy.

5. DECISIONAL RELEVANCE OF THE MEASURE: This index is used as a means for checking points of primary concern to the planner/manager to determine the adequacy of the medical facility. The planner/manager is primarily concerned with the value of the index between 0.0 and 0.5.

6. ASSOCIATED MEASURES:

Admission rate	Hospital efficiency index
Hospital capacity	Mean evacuation time

7. REFERENCES:

Evaluation of Final Report, Field Evaluation, Combat Support Hospital TOE (8-123).

BULLDOZER CUBIC MOVEMENT RATE

1. DEFINITION OF THE MEASURE: Bulldozer cubic movement rate is an index number based on the amount of cubic feet of earth moved by bulldozers in a specified time period. Input data are:

W = width of dozer blade (feet or meters)
D = working depth of dozer blade (feet or meters)
P = push distance (feet or meters)
T = turn-around time (cycle including shearing, loading, returning) in minutes

Relation of output to input is:

$$\text{Cubic movement rate} = \frac{W \times D \times P}{T}$$

2. DIMENSION OF THE MEASURE: ratio -- a rate in terms of cubic feet or meters of earth moved per minute or hour

3. LIMITS ON THE RANGE OF THE MEASURE: The output value can be any positive number. The rate computed is actually a maximum rate assuming total efficiency, and has to be multiplied by a fraction indicating expected efficiency in terms of personnel, environmental, or tactical hindrances.

4. RATIONALE FOR THE MEASURE: The measure directly addresses productivity of bulldozer operations.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate the effectiveness of a bulldozer or unit performing bulldozer operations.

6. ASSOCIATED MEASURES:
Grader spending rate
Area sprinkling rate

7. REFERENCES:
No ACN - Effectiveness Analysis of Equipment Mixes for Engineer Units

GRADER SPREADING RATE

1. DEFINITION OF THE MEASURE: Grader spreading rate is thenumber of square feet of dirt spread over a given area in an hour. Input data are:

W = width of working area (ft)
L = working distance (ft)
E = a working efficiency function
T = time worked (min)

Relation of output to input is:

$$\text{grader spreading rate} = \frac{W \times L \times E}{T}$$

2. DIMENSION OF THE MEASURE: ratio -- output is in terms of square feet per minute

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The efficiency function has to be defined as a dimenless value based on personnel efficiency and job difficulty.

4. RATIONALE FOR THE MEASURE: This measure addresses effectiveness of grader operation in terms of one of the primary aspects of its productivity.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate effectiveness of grader operation.

6. ASSOCIATED MEASURES:
Grader maintenance function

7. REFERENCES:
No ACN- Effectiveness Analysis of Equipment Mixes for Engineer Units, Logistics Document 19678B, pp. 216-219

BUCKET-LOADER EFFECTIVENESS

1. DEFINITION OF THE MEASURE: Bucket-loader effectiveness is the observed payload movement rate of bucket-loaders as a proportion of maximum possible movement rate. Input data are:

- C = capacity of bucket (in cubic feet)
- T_c = cycle time per bucket lift, including empty return time
- M = amount of payload actually moved (in cubic feet)
- T_o = time operation observed for measure

Relation of output to input is:

$$\text{bucket loader effectiveness} = \frac{M/T_o}{C/T_c}$$

2. DIMENSION OF THE MEASURE: RATIO -- A ratio of two rates, the observed rate divided by the possible rate. The output is a pure number.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive fraction. It is necessary to measure both productivity values in the same unit (cubic feet) and both time measures in the same unit (hours or minutes) as appropriate The measure increases in usefulness as the amount of time observed increases.

4. RATIONALE FOR THE MEASURE: The measure is a direct computation of how much work is produced as a fraction of the maximum amount that could be produced.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate the effectiveness of bucket-loaders, or bucket-loader operations with several machines.

6. ASSOCIATED MEASURES:
   - Actual/Potential Productivity Ratio
   - Earth Movement Rate (bulldozer)
   - Grader Spreading Rate
   - Water Distributor Sprinkling Rate

7. REFERENCES:
   No ACN, Effectiveness Analysis of Equipment Mixes for Engineer Units.

WATER DISTRIBUTOR AREA SPRINKLING RATE

1. DEFINITION OF THE MEASURE: Water distributor area sprinkling rate is the amount of area sprinkled by a water distributor in a specified time period. Input data are:

W = width of water sprinkler bar (feet or meters)
D = distance traveled by distributor while unloading one tankful of water (feet of meters)
T = turnaround time (time to fill, transport, empty, and return) in minutes

Relation of output to input:

$$\text{Sprinkling rate} = \frac{W \times D}{T}$$

2. DIMENSION OF THE MEASURE: ratio -- a rate in square feet or meters per minute or hour

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. The measure is actually a computation of maximum rate, and should be multiplied by a fraction representing the degree of expected efficiency after taking into account personnel, environmental, and tactical factors.

4. RATIONALE FOR THE MEASURE: This measure directly addresses productivity of a water distributor.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate a water distributor or a unit engaged in sprinkling operations.

6. ASSOCIATED MEASURES:
Bulldozer cubic movement rate
Grader area spreading rate

7. REFERENCES:
No ACN - Effectiveness Analysis of Equipment Mixes for Engineer Units

PRODUCTIVITY RATE (COMPACTOR TOOL)

1. DEFINITION OF THE MEASURE: The productivity rate of the compactor tool is the amount of square feet of earth compacted per hour. Input data are the number of square feet compacted and the number of hours worked. Relation of output to input is:

$$\text{compacting rate} = \frac{\text{number square feet compacted}}{\text{number hours}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a rate in terms of square feet per hour.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive value. A criterion for adequately compacted earth has to be defined.

4. RATIONALE FOR THE MEASURE: This is a direct performance measure of productivity of the engineer compactor tool.

5. DECISIONAL RELEVANCE OF THE MEASURE: The performance measure can be used to compare tools or units with compactor tools. Or the observed compacting rate can be divided by the maximum possible compacting rate (based on physical properties of the tool) for an effectiveness measure.

6. ASSOCIATED MEASURES:
   - Actual/potential productivity ratio
   - Bucket-loader effectiveness
   - Earth movement rate (bulldozer)
   - Grader spreading rate
   - Water spreading rate

7. REFERENCES:

No ACN, Effectiveness Analysis of Equipment Mixes for Engineer Units.

COMMAND, CONTROL AND COMMUNICATIONS

NUMBER OF ORDERS ISSUED

1. DEFINITION OF THE MEASURE: Number of orders issued is the simple number count of the orders issued for a given operation. Input data is the number of orders.

2. DIMENSION OF THE MEASURE:

INTERVAL -- number of orders

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The value of the output is a function of several factors and can not be dissociated from the conditions under which the measure was taken.

4. RATIONALE FOR THE MEASURE: This measure directly addresses the amount of command and control, and is considered an indication of the amount needed which relates to the cost or burden of command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare alternative command and control systems under the same conditions.

6. ASSOCIATED MEASURES:

Changes per order	Planning time
Repetitions per order	Pct actions initated in time

7. REFERENCES:

ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75, 15 Aug 67

REQUIRED NUMBER COMMANDS

1. DEFINITION OF THE MEASURE: Required number of commands is the simple number count of commands necessary to accomplish a stated mission. Input data is the total count of **commands**.

2. DIMENSION OF THE MEASURE: Interval -- A simple number count of commands. The measure could be taken in the form of a ratio, such as the average number of commands per mission, per objective, or per hour.

3. LIMITS ON THE RANGE OF THE MEASURE: There is no apparent limit on the output value; it can assume the value of zero or any positive integer. There is a serious limitation on the application of the measured output. It can only be applied in circumstances very similar to the circumstances under which it was observed.

4. RATIONALE FOR THE MEASURE: This measure can address difficulty in command and control in the sense that more commands may be required when command and control is more difficult. Alternatively if the difficulty of command and control is not variable, this measure may be an indication of facility in issuing commands.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare command and control systems in effectiveness when conditions causing commands are relatively stable. In the referenced study it was used to determine whether new devices complicated command and control by requiring more commands.

6. ASSOCIATED MEASURES:
   - Changes per order
   - Reaction time (time to order)

7. REFERENCES:
ACN 12944, Exploratory Examination in Night Operations Field Experiment 71.4 - Jun 68

REPETITIONS PER ORDER

1. DEFINITION OF THE MEASURE: Repetitions per order is the arithmetic mean of number of repetitions for each order issued. Input data are the number of orders issued and the number of repetitions of the same order (or part of an order) issued before the execution of the order is completed. Relation of output to input is:

$$\text{repetitions per order} = \frac{\sum^{n} (\text{number of repetitions issued each order})}{\text{number of orders issued}}$$

2. DIMENSION OF THE MEASURE: Ratio -- An average in terms of repetitions per order.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive number. The usefulness of the measure increases as the size of the denominator increases.

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of command and control indirectly. While some repetitions of orders (or parts of orders) are ordinarily to be expected, and unusually high average of changes indicates difficulties in command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare command and control systems on one aspect of effectiveness when other conditions are equivalent.

6. ASSOCIATED MEASURES:
   - Change per order
   - Rate of orders
   - Planning time
   - Mean length of orders

7. REFERENCES:
   ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75 - 15 Aug 67

CHANGES PER ORDER

1. DEFINITION OF THE MEASURE: Changes per order is the arithmetic mean of number of changes for each order issued. Input data are the number of orders issued and the number of changes made before execution of the order is completed. Relation of output to input is:

$$\text{changes per order} = \frac{\sum^{n}(\text{number of changes issued each order})}{\text{number of orders issued}}$$

2. DIMENSION OF THE MEASURE: ratio -- an average in terms of changes per order

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may be zero or any positive number. The usefulness of the measure increases as the size of the denominator increases.

4. RATIONALE FOR THE MEASURE: This measure addresses effectiveness of command and control indirectly. While some corrections to orders are ordinarily to be expected from a normally changing situation, an unusually high average number of changes indicates difficulties in command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare command and control systems on one aspect of effectiveness when other conditions are equivalent.

6. ASSOCIATED MEASURES:

Repetitions per order	Planning time
Rate of orders	Mean length of orders

7. REFERENCES:

ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75, 15 Aug 67

RATIO WARNING ORDERS TO OPORDERS

1. DEFINITION OF THE MEASURE: Ratio of warning orders to operation orders is the number of warning orders divided by the number of operation orders. Input data are the number of operation orders (including fragmentary orders) and number of warning orders. Relation of output to input is the quotient:

$$\text{ratio warning orders to operation orders} = \frac{\text{number warning orders}}{\text{number operation orders}}$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is a pure number expressing a ratio.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to unity.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of effectiveness of command and control, the issuance of warning orders prior to operation orders to assist reaction time. It is assumed that the higher the ratio is, the more effective is command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE. The measure is used to evaluate a command and control system. It is a secondary measure in the sense that it indirectly addresses something that can be measured directly, reaction time. It has been used to measure level of training.

6. ASSOCIATED MEASURES:
   - Number orders issued
   - Planning time forwarded
   - Time to decision
   - Reaction time

7. REFERENCES:

No AGN - Reserve Components Revised AIT, USCONARC, Mar 72

TIME TO DECISION

1. DEFINITION OF THE MEASURE: Time to decision is the proportion of time from receipt of mission to time of executing action that is devoted to the commander's decision. (This measure also called PLANNING TIME.) Input data are the time of receiving the mission (t_r), time order is approved (t_o) which is counted as the final decision, and time execution of the ordered action is to start (t_e). Relation of output to input is:

$$\text{time to decision} = \frac{t_o - t_r}{t_e - t_r}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a pure number expressing the proportion of total time available devoted to reaching a decision.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to unity. It could only be zero if the order is given without planning or consideration, and could only be unity if the order were not complete by the time the ordered action was to start.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of the command and control system, the amount of time consumed in planning and preparing the order. It is assumed that a more effective command and control system (including commander, staff, SOP's, and assisting technology) requires less of the available time for finalizing the order.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate a command and control system

6. ASSOCIATED MEASURES:
   - Number orders required
   - Planning time forwarded
   - Changes per order

7. REFERENCES:
   None - this is a potential measure

TIME FROM MISSION TO ORDER

1. DEFINITION OF THE MEASURE: Time from mission to order is the elapsed time at one echelon of command from the moment of receiving a mission from the next higher echelon to the moment of issuing the responsive order to the next lower echelon. Input data are the two chronological times. Relation of output to input is the subtracted difference:

time from mission to order = moment of issue of order minus moment of receipt of mission

2. DIMENSION OF THE MEASURE: Interval -- An elapsed time in minutes, hours, or days as appropriate. Several observations could be combined into a ratio measure such as the mean time or expected time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive measure. Since the main factors are nature of the mission and the echelon involved, the output value can not be separated from the conditions and these should probably be stated with the value, as for example, time from receipt of attack mission to battalion order.

4. RATIONALE FOR THE MEASURE: The measure directly addresses the timeliness of the command function. It includes planning time, decision time, and time to prepare and disseminate the order. It subsumes most of the important factors of difficulty in the command function, but does not include the factor of quality or soundness of the order.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative command and control systems on the timeliness aspect of effectiveness. Since the soundness of the order is not included, this measure would not be expected to stand alone, but would be used in conjunction with other measures.

6. ASSOCIATED MEASURES:

Planning time — Time to prepare order
Decision time — Dissemination time
(Any measure of soundness of order)

7. REFERENCES:

ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75 - Jul 69

PERCENT PLANNNING TIME FORWARDED

1. DEFINITION OF THE MEASURE: Percent planning time forwarded is the percentage of total planning time available that an echelon allows to all lower echelons. Input data are the total time from receipt of a mission (R) to time ordered to start execution (E), and time from receipt of mission (R) to issuance of the related order (O) to the next lower echelon. Relation of output to input is:

$$\text{Pct planning time forwarded} = \frac{R - O}{R - E} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of total preparation time allowed. Several observations could be combined to "mean percent planning time forwarded".

3. LIMITS ON THE RANGE OF THE MEASURE: Output can vary from zero to one hundred percent. It would be close to zero only when the order is given immediately to execute a contingency plan, or when an SOP is implemented. It would be 100% only if the echelon issuing the order used up all the preparation time, not issuing the order until the intended time of execution had come.

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of command and control by assessing how quickly planning is completed on an order issued in relation to the time available. Infantry School instruction includes the policy that each echelon should allow the next lower echelon 50% of the time it had available so that if a division receives a mission to attack in 24 hours it should have its attack order to the brigades within 12 hours, the brigades should issue orders to the battalions with 6 hours and so forth. This measure is superior to elapsed planning time which is only a measure of performance. This MOE is truly a measure of effectiveness because the best possible performance (zero percent) is included in the measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: This MOE is intended to assess the effectiveness of a command and control system. It takes into account planning time, decision time, and time to prepare and disseminate orders.

6. ASSOCIATED MEASURES: Elapsed planning time
Time to decision

7. REFERENCES:
No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PERCENT ORDERS CLARIFICATION REQUESTED

1. DEFINITION OF THE MEASURE: Percent orders clarification requested is the percentage of total orders issued including fragmentary orders, for which any subordinate element requested clarification. Input data are the number of orders issued and the number of those orders for which one or more subordinate elements requested clarification in whole or part. Relation of output to input is:

$$\text{percent orders clarification requested} = \frac{\text{number orders clarification requested}}{\text{number of orders issued}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage, in terms of percentage of orders.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any value from zero to one hundred percent. The measured is not very refined in that it ignores the effect of more than one request per order, ignores the possibilities of most requests coming from the same subordinate; and makes no distinction betdeen minor points and crucial ambiguities. A more refined measure could be constructed to take these into account.

4. RATIONALE FOR THE MEASURE: The measure addresses quality of the command and control system indirectly by assessing the clarity of orders. It is assumed that a more effective command and comtrol system has fewer requests for clarification.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate effectiveness of a command, control, and communucations system when the system is defined as including both commander and subordinates. The measure cannot be used alone because greater delay could increase clarity. This measure is used in conjunction with a timeliness measure.

6. ASSOCIATED MEASURES:

Time to decision
Planning time forwarded
Span of control
Changes per order
Repetitions per order
Reaction time

7. REFERENCES:

NO ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PROPORTION FRIENDLY ELEMENTS ENGAGED

1. DEFINITION OF THE MEASURE: Proportion friendly elements engaged is the quotient of the number of friendly elements erroneously engaged by fire to the number of all such friendly elements. Input data are the number of erroneous firing incidents and the total number of friendly elements. Relation of output to input is:

$$\text{proportion friendly elements engaged} = \frac{\text{number erroneous fires on friendly}}{\text{number friendly elements}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a proportion in decimal form.

3. LIMITS ON THE RANGE OF THE MEASURE: A proportion can vary from zero to one. The measure is made more complex if it includes different types of friendly elements.

4. RATIONALE FOR THE MEASURE: This measure addresses one of the most catastrophic failures in command-control-communications, the erroneous firing on friendly elements. In the referenced study it was applied to mistaken engagements of friendly aircraft by friendly air defense weapons.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in assessing the accuracy of command-control-communications in the situation where erroneous fire on friendly elements is possible in the event of failure.

6. ASSOCIATED MEASURES:

Required number commands
Mean dissemination time
Changes per order
Percent transmissions completed
Percent orders clarification requested

7. REFERENCES:

ACN 10784. Troop Test REDEYE, 1967

MEAN DISSEMINATION TIME

1. DEFINITION OF THE MEASURE: Mean dissemination time is the time required to disseminate an order, directive, or warning to all elements at the next lower echelon of command. Input data are each time the order is approved and each time the last immediate subordinate headquarters acknowledges receipt. Relation of output to input is:

$$\text{mean dissemination time} = \frac{\sum^{n}\left[(\text{each time approval})-(\text{each time acknowledged})\right]}{\text{number orders}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is an arithmetic mean in terms of average number of minutes and seconds

3. LIMITS ON THE RANGE OF THE MEASURE: The measure may assume any positive value. The value is usually in terms of minutes since the only time involved is the time required to deliver or transmit a single message. A convention must be established for the possibility that an element fails to receive an order.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of command and control directly, timeliness of disseminating orders. This is one area of command and control that can be expected to improve with technology.

5. DECISIONAL RELEVANCE OF THE MEASURE: The usual application of the measure is evaluation of proposed technology to assist command and control. The time measure does not stand alone but has to be used in conjunction with a measure of accuracy.

6. ASSOCIATED MEASURES:
   - Repetitions per order
   - Changes per order
   - Span of command

7. REFERENCES:
   - ACN 16849, MASSTER II Test
   - ACN 17036, MASSTER III Test
   - ACN 10784, Troop Test REDEYE

PERCENT ACTIONS INITIATED BY TIME ORDERED

1. DEFINITION OF THE MEASURE: Percent actions initiated by time ordered is the percentage of all actions initiated in response to orders that are initiated within the time specified by the order. (If the order does not specify a distinct time, it is counted as initiated on time regardless of delay). Input data are the times ordered and the times action is initiated. Relation of output to input is:

$$\text{percent actions initiated on time} = \frac{\text{number actions initiated by time ordered}}{\text{number actions ordered}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio --output is in the form of a percentage

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any value from zero to one hundred percent. The usefulness of the measure increases as the number of orders in the denominator with specified times increases.

4. RATIONALE FOR THE MEASURE: This measure addresses the timeliness of reaction to orders.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be an indication of the effectiveness of command and control in the sense that when other factors are equal better command and control leads to faster reaction. This may make the measure useful in comparing alternative systems of command and dontrol. Alternatively command and control may be held constant and this measure may distinguish between reaction systems.

6. ASSOCIATED MEASURES:
- Time to first fire
- Changes per order
- Repetitions per order
- Planning time
- Mean length of orders
- Percent moves completed on time

7. REFERENCES:
ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75, 15 Aug 67

NUMBER OF OPTIONS REMAINING

1. DEFINITION OF THE MEASURE: Number of options remaining is the number count of options available to a decision-maker. Input data are the number of decision points open (d_i), the number of options for each decision point (O_i) and the number of decisions (n). Output is:

$$\text{number options remaining} = (d_1)(O_1) + (d_2)(O_2) + \ldots (d_n)(O_n) = \sum_{i=1}^{n} (d_i o_i)$$

2. DIMENSION OF THE MEASURE: Interval -- The output is a positive potential number of options. It can be used in the form of "proportion of options remaining."

3. LIMITS ON THE RANGE OF THE MEASURE: The output is a positive integer equal to or greater than twice the number of decision points. There is often some difficulty in determining the two input values and some tendency to estimate an infinite or very high number of options for a decision point.

4. RATIONALE FOR THE MEASURE: The measure is a direct indication of the amount of flexibility left to a commander. It is based on the theorem that more options is always more desirable.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to gauge the effectiveness of a command and control system. In the form "proportion of options remaining" the situation is compared to the number of options available before a decision was made.

6. ASSOCIATED MEASURES:
   Amount of information conveyed
   Time to decision

7. REFERENCES:

No ACN - "Candidate MOE for Air Strike Systems," Naval Weapons Center Document #TP4687.

PROPORTION FIRE REQUESTS BEYOND RANGE

1. DEFINITION OF THE MEASURE: Proportion fire requests beyond range is the proportion of all fire missions requested (or required in the case of a simulation) that are not fired because target is beyond range. Input data are total number of fire missions required and number denied because target is beyond range. Relation of output to input is:

$$\text{proportion fire requests beyond range} = \frac{(\text{nr. req's}) - (\text{nr. denied for range})}{\text{nr. req's}}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a fraction expressing proportion.

3. LIMITS ON THE RANGE OF THE MEASURE: Output can vary from zero to unity.

4. RATIONALE FOR THE MEASURE: This measure is a direct assessment of the effectiveness of a firepower system in meeting requirements, taking range into account.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate a firepower system. Indirectly, it may be used to evaluate a command and control system because the largest single factor in the measure may be deployment of fire support in relation to the supported force mission.

6. ASSOCIATED MEASURES: Percent fire request met
Maximum effective range
Area coverage

7. REFERENCES:

No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

COMMUNICATIONS PERFORMANCE INDEX

1. DEFINITION OF THE MEASURE: This communications index is a weighted sum of a communications system's performance in relation to its requirements. Input data are the relative weights of each requirement ($W_1 \ldots W_n$) and the performance ($P_1 \ldots P_n$) observed in each requirement ($R_1 \ldots R_n$). Relation of output to input is:

$$\text{index} = W_1 \left(\frac{P_1}{R_1}\right) + W_2 \left(\frac{P_2}{R_2}\right) + \ldots W_n \left(\frac{P_n}{R_n}\right) = \sum_{i=1}^{n} \left[W_i\left(\frac{P_i}{R_i}\right)\right]$$

Examples of system requirements are: direct communications capacity, organic communications equipment, conference call capability, specific range, security, mobility, message hard copy, dependability, and vulnerability, each of which is measured directly or rated by evaluators on a common scale.

2. DIMENSION OF THE MEASURE: Index -- A weighted sum.

3. LIMITS ON THE RANGE OF THE MEASURE: The values assumed by the output depend on the performance/requirements scale and weights. The maximum value is n times the maximum scale, times the total weight. The measure is limited by the selected of requirements and weights.

4. RATIONALE FOR THE MEASURE: The measure is intended to combine performance in all requirements to preclude over-valueing some requirements.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative communications systems.

6. ASSOCIATED MEASURES:
   - Percent messages completed
   - Communications system capacity

7. REFERENCES:

ACN 02747, "Theater Army Communications Systems Requirements, 1965-70."

PERCENT TRANSMISSIONS COMPLETED

1. DEFINITION OF THE MEASURE: Percent transmissions completed is the percentage of all communications transmissions attempted that are completed. Input data are the number of attempts to transmit a message (T) and the number of these attempts that are completed (C). Relation of output to input is:

$$\text{percent transmissions completed} = \frac{C}{T} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a percentage of transmission attempts.

3. LIMITS ON THE RANGE OF THE MEASURE: The output could vary from zero to one hundred percent. This measure has a weakness in that it ignores differences in length and importance of messages not completed.

4. RATIONALE FOR THE MEASURE: The measure addresses amount of communications directly. It is a true measure of effectiveness because it assesses what proportion of the best possible performance is accomplished. Because this measure does not require recording the content of messages, it is relatively inexpensive to take.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate communications systems. It can be applied to a comparison of alternative communications procedures or equipment.

6. ASSOCIATED MEASURES:
   - Message rate
   - Message backlog

7. REFERENCES:
   - ACN 06930, Troop Test Frontier Shield, Feb 67
   - ACN 03210, TASS Field Evaluation, Jun 71
   - No ACN - Reserve Components Revised ATT, USCONARC, Mar 72
   - ACN 10784, Troop Test REDEYE, 1967

MEAN TIME MESSAGE DELIVERY

1. DEFINITION OF THE MEASURE: Mean time message delivery is the arithmetic average of the observed times to communicate a message from sender to addressee. It includes time waiting to get into communications system, time lost to unsuccessful attempts, time to copy, receive, and time to distribute from message center to addresses. Relation of output to input is the total elapsed time:

$$\text{mean time message delivery} = \frac{\sum^{n} \left[\text{each (arrival time)} - \text{(start time)}\right]}{\text{number messages}}$$

2. DIMENSION OF THE MEASURE: Interval -- output is an elapsed time in seconds, minutes, or hours

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be any positive value. It is usually necessary to subdivide this measure into types of message both for precedence (FLASH, IMMEDIATE, PRIORITY, ROUTINE) and means of transmission (radio, telephone, teletype, courier) to make the output meaningful.

4. RATIONALE FOR THE MEASURE: This measure addresses timeliness of communications directly. Any difficulties in a communications system would probably be noticeable in mean delivery times before they can be detected in grosser measures such as percent messages completed.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate a communications system. It could be used indirectly to evaluate other systems, for example as a subtle measure of whether a proposed doctrine or organization results in command, control, and communications problem.

6. ASSOCIATED MEASURES:
   - Percent transmissions completed
   - Message rate
   - Message backlog
   - Communications system capacity

7. REFERENCES:
   - ACN 06930, Troop Test Frontier Shield, Feb 67
   - ACN 03210, TASS Field Evaluation, Jun 71
   - No ACN, Reserve Components Revised ATT, USCONARC, Mar 72
   - ACN 10784, Troop Test REDEYE, 1967

MESSAGE RATE

1. DEFINITION OF THE MEASURE: Message rate is the number of messages transmitted per time period. Input data are the number of messages transmitted and time elapsed. Relation of output to input is:

$$\text{message rate} = \frac{\text{number of messages transmitted}}{\text{elapsed time}}$$

Alternatively, if data is available expressing cumulative messages transmitted as a function of time, the rate can be computed as the first derivative.

2. DIMENSION OF THE MEASURE: Ratio -- a rate in terms of messages per hour or messages per day

3. LIMITS ON THE RANGE OF THE MEASURE: The output is not meaningful until at least one message has been transmitted, and is more stable as the length of elapsed time increases. The output is any positive value, and may be fractional. Resolution of the measure depends on unit of time used.

4. RATIONALE FOR THE MEASURE: This measure addresses capacity of a communications system. It is a performance measure rather than a measure of effectiveness, but could be converted to an MOE by dividing observed performance by maximum possible message rate.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to compare or evaluate communications systems in terms of capacity.

6. ASSOCIATED MEASURES:
   Percent transmissions completed
   Peak traffic load

7. REFERENCES:
   ACN 06492, Communications - Electronics Study - 75

MESSAGE BACKLOG

1. DEFINITION OF THE MEASURE: Message backlog is the number of messages awaiting transmission by a communications system. In its simplest form, current message backlog, it is a simple number count of waiting messages, or the difference:

message backlog = messages submitted minus messages transmitted

In the form, peak message backlog, it is the examination of a historical record of messages submitted and transmitted in each time period for the time of greatest difference.

2. DIMENSION OF THE MEASURE: Interval -- The output is a number count in terms of number of messages. Alternatively if data is available over time a ratio measure can be computed in terms of "mean message backlog" or "expected message backlog."

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any postive integer. (In ratio form it may be fractional and negative.)

4. RATIONALE FOR THE MEASURE: The measure directly addresses the effectiveness of a communications system in terms of amount and timeliness of production. Furthermore the measure is directly relevant in tactical terms because message backlog is directly related to tactical success.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate or compare communications systems.

6. ASSOCIATED MEASURES:
   Message handling rate
   Communications system capacity

7. REFERENCES:
   ACN 06930, Troop test Frontier Shield.
   ACN 17036, MASSTER III Test, Oct 71.

MEAN NUMBER TRANSMISSIONS REQUIRED

1. DEFINITION OF THE MEASURE: Mean number transmissions required is the arithmetic average of radio transmissions made each time a specified type of action is expected. Input data are the number counts of messages initiated for each execution. Relation of output to input is:

$$\text{mean number transmissions required} = \frac{\text{(number transmissions per execution)}}{\text{number executions}}$$

2. DIMENSION OF THE MEASURE: ratio -- a mean in terms of mean number of transmissions

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be zero or any positive value. The usefulness of the measure increases as the number of repetitions of executing the action increases. The output value can not be dissociated from the type of action from which it was derived.

4. RATIONALE FOR THE MEASURE: This measure addresses command and control indirectly. A larger number of transmissions is assumed to indicate a greater amount of command and control. After normal variation is averaged out, an unusually high mean indicates command/control difficulties.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to compare alternative systems in one aspect of command and control burden.

6. ASSOCIATED MEASURES:
   - Mean number orders issued
   - Mean number changes per order

7. REFERENCES:
   ACN 13223 - Land Navigation Systems Troop Test, Jul 70

PERCENT NET CAPACITY UTILIZATION

1. DEFINITION OF THE MEASURE: Percent net capacity utilization is the percentage of the total capacity of a communications net that is utilized. Input data are total time in minutes that net is observed and time in minutes that the net is carrying any traffic. Relation of output to input is:

$$\text{percent net capacity utilization} = \frac{\text{time net carries traffic (min)}}{\text{total time net is observed (min)}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a percentage of time, such as 25% net capacity usage in 24 hours.

3. LIMITS ON THE RANGE OF THE MEASURE: Output can vary from zero to one hundred percent. Zero percent would indicate an available net not used; one hundred percent would usually indicate a backlog. Since capacity usage would be expected to vary over time, the output value cannot be dissociated from the time period observed.

4. RATIONALE FOR THE MEASURE: The measure is an indication of communications systems effectiveness in the sense of how much potential capacity is used. In theory 100% usage is ideal, provided backlog is within acceptable limits.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to assess the necessity of a net, as in ACN 16849. More often it is used to determine whether nets approach overloading, as in ACN's 06930, 17036, 03210, and 16819. Often the useful figure is not ordinary utilization but the percent utilization at peak usage.

6. ASSOCIATED MEASURES:
   - Mean time message delivery
   - Message backlog
   - Message rate
   - Percent transmissions completed

7. REFERENCES:
   - ACN 16849, MASSTER II Test
   - ACN 17036, MASSTER III Test
   - ACN 06930, Troop Test Frontier Shield
   - ACN 03210, TASS Field Evaluation
   - No ACN, Candidate MOE for Air Strike Systems, Naval Weapons Center Report #TP4687

PERCENT COM LINKS WITH ALTERNATE ROUTE

1. DEFINITION OF THE MEASURE: Percent comm links with alternate route is the percentage of all established node-to-node communications links that also have an existing alternate route for communications. The alternate may be defined as of the same means only (i.e., wire links with alternate wire) or by any means (i.e., wire links with radio, teletype, or other alternate means). Relation of output to input is:

$$\text{percent comm links with alternate route} = \frac{\text{number links with alternate}}{\text{number links}} \times 100$$

2. DIMENSTION OF THE MEASURE: Ratio -- output is a percentage.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may vary from zero to one hundred percent. Definition of alternate must be established. The measure has a weakness in that nodes must be defined so that both a link and its alternate are not counted as two links each with an alternate inflating the output value.

4. RATIONALE FOR THE MEASURE: The measure addresses the effectiveness of a communications system indirectly in gauging its probable resistance to disruption. This is a secondary measure because its resistance to disruption can be measured directly by primary measures such as percent of transmissions completed and mean delivery time.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually used to assess where difficulties in a communications system are when difficulties are revealed by primary measures. It might, however, be applicable for measuring potential resistance when it is impractical to compute actual disruption.

6. ASSOCIATED MEASURES: Percent transmissions completed
Mean message delivery time
Message rate
Message backlog

7. REFERENCES:

ACN 03210, TASS Field Evaluation, Jun 72
No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

COMMUNICATIONS INTERCEPTION SUSCEPTIBILITY

1. DEFINITION OF THE MEASURE: Communications interception susceptibility is the proportion of messages that can be intercepted. Input data is the number of messages transmitted under circumstances in which interception is possible and the total number of messages intercepted. Relation of output to input is:

$$\text{interception susceptibility} = \frac{\text{number of messages which could be intercepted}}{\text{total messages transmitted}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is in the form of proportion of total messages, such as .25 susceptible.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can vary from zero to unity. In dealing with susceptibility rather than actual observed success in interception it is necessary to make an educated decision as to each message on the basis of the conditions of transmission.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of vulnerability of a communications system. It is noted that this measure results in the highest possible value, the highest theoretic proportion.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate communications systems.

6. ASSOCIATED MEASURES:
   - Percent successful interception attempts
   - Percent messages intercepted

7. REFERENCES:

ACN 02908, Field Army Requirements for Tactical Communications, Oct 66

PERCENT SUCCESSFUL INTERCEPTION ATTEMPTS

1. DEFINITION OF THE MEASURE: Percent successful interception attempts is the percentage of attempts to intercept communications that result in an interception. Input data are number of attempts and number of interceptions. Relation of output to input is:

$$\text{percent successful interception attempts} = \frac{\text{number of interceptions}}{\text{number of interception attempts}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a percentage of interception attempts.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to one hundred percent. The measure is always limited to the means used to intercept and cannot be disassociated from the equipment and procedures used.

4. RATIONALE FOR THE MEASURE: The measure is an indication of the probable amount of interception that can be done under tactical circumstances.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate the success of a countermeasures system or a counter-countermeasures system. It is usually extrapolated in the sense that if 50% of attempts are successful it is usually surmised that the interceptor would be able to intercept on half of all attempts if he increased his attempts.

6. ASSOCIATED MEASURES:
    Communications Interception Susceptibility
    Percent messages intercepted

7. REFERENCES:
    ACN 17036, MASSTER III Test

PERCENT MESSAGES INTERCEPTED

1. DEFINITION OF THE MEASURE: Percent messages intercepted is the percentage of all messages transmitted that are intercepted. Input data are the number of messages transmitted and the number of interceptions. Relation of output to input is:

$$\text{percent messages intercepted} = \frac{\text{number interceptions}}{\text{number messages transmitted}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a percentage of all messages.

3. LIMITS ON THE RANGE OF THE MEASURE: Output can assume values from zero to one hundred percent. The usefulness of the measure increases as the number in the denominator increases. The output value depends on the circumstances of interception attempts so that the value cannot be disassociated from the circumstances under which it was derived.

4. RATIONALE FOR THE MEASURE: This measure goes directly to the tactical aspect of susceptibility to interception. It has more direct tactical application than theoretic susceptibility or percentage of successful interceptions because neither of these tells just how much traffic is lost to interception.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure evaluates effectiveness of countermeasures or counter-countermeasures in a tactically relevant sense.

6. ASSOCIATED MEASURES:
   - Communications interception susceptibility
   - Percent successful interception attempts

7. REFERENCES:

ACN 06930, Troop Test Frontier Shield, 1967

MEAN TIME RESPONSE TO JAMMING

1. DEFINITION OF THE MEASURE: Mean time response to jamming is the arithmetic mean of each elapsed response time to enemy jamming of friendly communications. Input data are the times of detection of jamming, times of switching frequency, and number of jamming attempts. Relation of output to input is:

$$\text{mean time response to jamming} = \frac{\text{each elapsed response time}}{\text{number jammings}}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a mean time in seconds and minutes

3. LIMITS ON THE RANGE OF THE MEASURE: The measure may assume any positive value. A convention must be established for a jamming incident that is ended before any response is made.

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of one countermeasure aspect of a communications system.

5. DECISIONAL RELEVANCE FOR THE MEASURE: The measure is used to evaluate effectiveness of a countermeasure system. This measure does not stand alone, but is used in conjunction with measures of effectiveness of communications. It was used in the referenced study as a measure of training.

6. ASSOCIATED MEASURES:
   - Percent transmissions completed
   - Mean message delivery time
   - Message rate

7. REFERENCES:

No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

FIREPOWER

NUMBER ROUNDS FIRED

1. DEFINITION OF THE MEASURE: The number of rounds fired is the number of rounds expended from start to end of engagement. Relation of output to input is:

$$\text{number of rounds fired} = \sum_{i=1}^{n} (\text{rounds fired})$$

2. DIMENSION OF THE MEASURE: Interval -- A number in terms of rounds, tons, DOA, or other suitable expressions of ammunition expenditure.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive value. The meaningfulness of the measure increases as the time period observed increases. However, the output value cannot be dissociated from the time period involved.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of firepower directly, amount of fire. While it would not ordinarily stand alone, it can be combined with timeliness and accuracy of fire to more nearly cover the whole issue of firepower.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable on at least two levels. At the system hardware level it can be used to discriminate among individual weapons in fire capability. At a higher level it can discriminate among whole units, alternative procedures, or larger material systems.

6. ASSOCIATED MEASURES:

Ammunition expended	Time to first fire
Remaining ammunition	Percent of rounds hit
Casualties inflicted	Percent of targets hit
Loss exchange ratio	Circular error probable

7. REFERENCES:

ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75, Field Experiment 65.1 - Aug 67

PERCENT OF BASIC LOAD EXPENDED

1. DEFINITION OF THE MEASURE: Percent of basic load expended is the amount of ammunition expended as a proportion of basic load. Input is number count of rounds, tons, or DOA expended, and the number of rounds, tons, or DOA in the basic load. Relation of output to input is:

$$\text{pct. of basic load expended} = \frac{\text{amount expended}}{\text{amount in basic load}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- a quotient of two number counts. It could be used in the form of a simple decimal proportion or fraction. Unit of measure of output is a pure number expressing a ratio.

3. LIMITS ON THE RANGE OF THE MEASURE: ·n assume any positive value. Is limited in applicability to the time period and circumstances observed, so that the measure cannot be disassociated from the conditions of its measurement.

4. RATIONALE FOR THE MEASURE: This measure addresses cost directly, and sustainability indirectly.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to distinguish among competing firepower systems of about equal performance in other respects. Or it can be used to supplement a description of a firepower system for greater refinement in cost or probable sustainability.

6. ASSOCIATED MEASURES:
   - Ammunition expenditure rate
   - Required rate of ammunition resupply

7. REFERENCES:

ACN 03010, Infantry Rifle Unit Study - 75.
ACN 06930, Troop Test Frontier Shield, Dec 66.
ACN 03067, IRUS Field Experiment 65.1, Aug 67.
ACN 05546, Army Air Mobility Evaluation, Feb 65.

PERCENT TARGETS HIT

1. DEFINITION OF THE MEASURE: Percent targets hit is the percentage of all enemy targets presented that are hit by one or more rounds. Input data are the number of targets presented and the number of targets hit. Relation of output to input is;

$$\textbf{percent of targets hit} = \frac{\text{number targets hit}}{\text{number targets presented}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is in terms of a percentage of targets.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any value from zero to one hundred percent. The measure is somewhat crude in the sense that targets with only one hit are counted the same as targets destroyed by many hits. Furthermore, the number of targets presented must be defined; it may be all enemy, all enemy within range, those enemy that might reasonably be considered tactical targets, or only targets actually fired at.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of firepower directly, but is only an indirect indication of accuracy of fire. It more closely approaches tactical significance than percent of rounds hitting, but is not as refined a measure. It is easier to take measures of the casualties inflicted or other measures of damage, but not as tactically significant.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare firepower systems on the amount of firepower in a manner approaching tactical significance.

6. ASSOCIATED MEASURES:
   - Number rounds hit
   - Percent rounds hit
   - Casualties inflicted

7. REFERENCES:

   - ACN M3523, Small Arms Weapons Systems (SAWS) Field Experiment 65.4 - May 66
   - ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75, Field Experiment 65.1 - Aug 67
   - ACN 06081, Army Small Arms Weapons Systems Troop Acceptability Test.
   - ACN 16975, Airborne STANO Systems, Part II.
   - ACN 02874, Troop Test: Overall Effectiveness of Artillery Organizations, Doctrine and Concepts, Aug 65

CASUALTIES PER ROUND

1. DEFINITION OF THE MEASURE: Casualties per round is the ratio between casualties inflicted and rounds fired. Input are number count of casualties inflicted and number count of rounds fired. Relation of output to input is:

$$\text{casualties per round} = \frac{\textbf{number casualties}}{\textbf{number rounds fired}}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is in the form "casualties per round." In this form, the output value is usually a small fraction of a casualty.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful until both numerator and denominator are greater than zero. The output then takes any value above zero. It is usually a small fraction because few rounds kill even one enemy, but could theoretically assume any positive value.

4. RATIONALE FOR THE MEASURE: The measure addresses kill productivity of a weapons system directly.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure can distinguish among weapons systems in kill productivity. It takes into account both chance of killing hits and the number of casualties per hit.

6. ASSOCIATED MEASURES:
   - Loss exchange ratio
   - Rounds per casualty

7. REFERENCES:
   None; this is a proposed potential measure.

ROUNDS PER CASUALTY

1. DEFINITION OF THE MEASURE: Rounds per casualty is the number of rounds expended divided by the number of casualties inflicted. Casualties can be a number count of any appropriate strength indicator, such as personnel, tanks, weapons, or other. Relation of output to input is:

$$\text{rounds per casualty} = \frac{\textbf{number of rounds expended}}{\textbf{number of casualties inflicted}}$$

2. DIMENSION OF THE MEASURE: Ratio -- rounds per casualty. If accumulated over several engagements the form may be changed to average rounds per casualty. Or the form may be inverted for casualties per round, which would ordinarily be a small fraction.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is meaningless until at least one round has been expended and at least one casualty inflicted. It becomes more useful as the number of rounds increases. It is more difficult to apply when differing types of casualty losses or different types of rounds must be combined.

4. RATIONALE FOR THE MEASURE: This can be a useful measure of firepower effectiveness, especially in comparing similar but different weapons or ammunition systems. In its inverse form, casualties per round, it is an indication of probability of kill (P_k). It was used in the referenced study to rank order weapons mixes in firepower potential.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure would ordinarily be used to compare weapons systems against a certain threat.

6. ASSOCIATED MEASURES:
   - Relative ammo expenditure to casualties ratio
   - Loss exchange ratio

7. REFERENCES:
   - ACN 03010, Infantry Rifle Unit Study - 75.
   - ACN 12757, Secondary Armament for the Main Battle Tank-70.

PERCENT TARGET DESTRUCTION

1. DEFINITION OF THE MEASURE: Percent target destruction is the percentage of an attacked target that is assessed as killed, destroyed, or neutralized. Input data are the size of the target and the amount destroyed. This input values may be in terms of number of personnel, number of vehicles or major weapons, size in terms of square meters, number of buildings or oil tanks, length of road or track, or any appropriate count of target size. Relation of output to input is:

$$\text{percent target destruction} = \frac{\textbf{amount of target destroyed}}{\textbf{size of target (area, volume)}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A proportion in terms of percent of whole target, such as, 30% of troops, 30% of area, 30% of road length, and so forth.

3. LIMITS ON THE RANGE OF THE MEASURE: A percentage may vary from zero to one hundred percent. The main limit to this measure is the problem of measuring damage. The measure is constrained by the necessity of expressing both the target size and the amount of damage in numerical form.

4. RATIONALE FOR THE MEASURE: The measure addresses one aspect of firepower directly, the amount of damage done. Furthermore, the amount of damage is expressed as a proportion of total target, for convenient usage.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate or compare firepower systems.

6. ASSOCIATED MEASURES:
   - Percent target hits
   - Percent rounds hit
   - Range at firing
   - Casualties inflicted
   - Proportion Remaining Force

7. REFERENCES:

No ACN, "Candidate Measures of Effectiveness for Air Strike Systems, Naval Weapons Center #TP4687, China Lake, Cal., - Sep 69

ACN 02874, Troop Test: Overall Effectiveness of Artillery Organizations, Doctrine and Concepts, Aug 65

DEGREE OF NEUTRALIZATION

1. DEFINITION OF THE MEASURE: Degree of neutralization is the proportion of a force that is killed plus the proportion suppressed. Unit of measure of the three inputs is any suitable number count of force size, such as number of personnel, tanks, weapons, or other. Suppression is defined as not killed but not operating. Relation of output to input is:

$$\text{degree of neutralization} = \frac{\text{number killed} + \text{number suppressed}}{\text{total number in force}}$$

2. DIMENSION OF THE MEASURE: Ratio -- a pure number expressing a ratio between two counts of force size. May be expressed in terms of a fraction, proportion, or percentage of force size. If measures are taken over time, the MOE may be computed in terms of average degree of neutralization, rate of neutralization, or probability of neutralization.

3. LIMITS ON THE RANGE OF THE MEASURE: Number killed and number suppressed must be held exclusive, i.e., one may not be counted as both. The measure is not meaningful until at least one has been counted killed or neutralized. The measure is tied to a given point in time because the number suppressed may fall or rise.

4. RATIONALE FOR THE MEASURE: The measure is superior to proportion killed at a given time because suppressed are no more effective than killed at that moment.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in the case of comparing doctrinal or materiel concepts that have appreciable suppression effects in addition to killing capability.

6. ASSOCIATED MEASURES:
   - Degree of win
   - Probability of kill
   - Loss exchange ratio

7. REFERENCES:

ACN 15758, Army Small Arms Requirements Study 1 (ASARS I), Vol. IV, Jun 70

AVERAGE NUMBER OF RED TANKS KILLED

1. DEFINITION OF THE MEASURE: Average number of red tanks killed is the sum of red tanks killed in each engagement divided by the number of engagements. Input data are number counts of tanks killed and number count of engagement. Relation of output to input is:

average number of red tanks killed =

$$\frac{\text{SUM: number tanks killed each engagement}}{\text{number engagements}}$$

2. DIMENSION OF THE MEASURE: Average number -- output measured in number of tanks.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful until at least one tank has been killed. The measure is limited in that it is an absolute number and its interpretation depends on the number of tanks participating but this is not a part of the measure. The measure is not reliable when the denominator is small.

4. RATIONALE FOR THE MEASURE: Used as a primary measure when the mission of the competing candidates is to kill tanks. It is not considered a strong measure when standing alone, but is a basic measure when used in conjunction with other measures.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is clearly a valid one of antitank effectiveness, and becomes increasingly reliable as the number of engagements increases. The measure is useful when all other factors are held constant or measured concurrently.

6. ASSOCIATED MEASURES:

Degree of blue win
Proportion of red losses
Expected remaining tank killing capability

7. REFERENCES:

ACN 17018, Antitank Weapons Systems Requirements Study

FIRING RATE

1. DEFINITION OF THE MEASURE: Firing rate is the number of rounds fired within a specified unit of time. Input data are a number count of rounds fired and elapsed time. Relation of output to input is:

$$\text{firing rate} = \frac{\text{number of rounds fired}}{\text{elapsed time}}$$

2. DIMENSION OF THE MEASURE: ratio --- a ratio in terms of rounds per second, minute, hour, or any suitable unit of time

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be any positive value. The measure is not meaningful until at least one round has been fired, and increases in usefulness as the period of time increases. Since firing rate may change over time, the output value can not be dissociated from the time period observed.

4. RATIONALE FOR THE MEASURE: The measure takes into account time required to acquire, aim, and order fire and the cyclic rate of the weapon system.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is directly applicable to the computation of fire potential, and may be used to evaluate or compare weapons systems.

6. ASSOCIATED MEASURES:
   - Time to acquire
   - Time to reload
   - Ammo expenditure rate
   - Time to adjust
   - Cyclic rate

7. REFERENCES:
   ACN 06081 - Army Small Arms Weapons System Troop Acceptability Test

TIME TO FIRST FIRE

1. DEFINITION OF THE MEASURE: Time to first fire is the elapsed time from detection of a target to arrival of the first reaction firing round on the target. Input data are the moment of detection and the moment of arrival of the first round. Relation of output to input is:

time to first round = time of arrival of first round minus time of detection

2. DIMENSION OF THE MEASURE: Interval -- Output is an elapsed time in seconds.

3. LIMITS ON THE RANGE OF THE MEASURE: Output can assume any positive value. An absolute measure like this cannot be separated from the conditions under which it is taken. If several such measures are taken they can be combined into a ratio measure such as "mean time to first round" or "expected time to first round."

4. RATIONALE FOR THE MEASURE: This is a direct measure of the timeliness of fire. It subsumes the times required to recognize, identify, and locate a target plus the times to communicate a fire request, fire the weapon system, and flight time of the projectile. In general it is a measure of fire reaction effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative systems for bringing fire to bear; for example, competing forward observer procedures, alternative fire control materiel, candidate tactics, or proposed organizations.

6. ASSOCIATED MEASURES:

Time to acquisition	Probability of kill
Cumulative exposure time	Probability of survival

7. REFERENCES:

ACN 17271, Ability to Adjust Artillery on Moving Materiel Targets Field Experiment 32.1

ACN 18288, Artillery versus Moving Target Follow-On (REACT)

ACN 18171, Attack Helicopter Daylight Defense Field Experiment 43.6

ACN 03067, Infantry Rifle Unit Study (IRUS), 1970-75, Field Experiment 65.1, Aug 67

ACN 16914, M60A1 Add-On Stabilization Troop Test, Apr 72

ACN M1144, Army Aircraft Survivability Field Experiment 63.6, Jun 66

ACN 15961, SHILLELAGH Field Experiment 11.6

No ACN, "Candidate MOE for Air Strike Systems," Naval Weapons Center Document #TP4687

No ACN, Systems Effectiveness Status Report (PERSHING), Feb 72

TIME TO ADJUST

1. DEFINITION OF THE MEASURE: Time to adjust is the elapsed time from start to completion of adjusting a fire mission. Input data are the start time and the completion time, and relation of output to input is the difference:

time to adjust = moment of completing adjustment minus moment of starting adjustment

2. DIMENSION OF THE MEASURE: Interval -- A simple elapsed time in seconds, minutes, hours, or any suitable expression of chronological time. It may also be in the ratio form "mean time to adjust".

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value.

4. RATIONALE FOR THE MEASURE: This measure addresses timeliness of adjustment directly. It is important because the nature of the target may change during the adjustment if the time is too long.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in comparing adjustment of fire systems in timeliness of adjustment. Systems would usually be observer teams with their equipment and techniques.

6. ASSOCIATED MEASURES:

Time to acquisition
Rounds to adjust

7. REFERENCES:

ACN 7395, Ground Observer Probabilities of Acquisition and Adjustment Field Experiment 31.1 - Sep 68

ROUNDS TO ADJUST

1. <u>DEFINITION OF THE MEASURE</u>: Rounds to adjust is the number of rounds fired in the course of adjusting a fire mission. Input data are the number of rounds fired.

2. <u>DIMENSION OF THE MEASURE</u>: Interval -- A simple number count of rounds.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: Output may assume any positive integer value.

4. <u>RATIONALE FOR THE MEASURE</u>: This measure addresses the effectiveness of adjustment is the sense that fewer adjustment rounds is always better.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure may be used to compare alternative adjustment systems in effectiveness. A fire adjustment system is ordinarily an observer team with its equipment and procedures.

6. <u>ASSOCIATED MEASURES</u>:
   - Time to acquisition
   - Time to adjust

7. <u>REFERENCES</u>:
   ACN 7395, Ground Observer Probabilities of Acquisition and Adjustment Field Experiment 31.1 - Sep 68

TIME TO FIRST HIT

1. DEFININITION OF THE MEASURE: Time to first hit is the elapsed time from initiation of firing to the first round on target. Input data are the two chronological times. Relation of output to input is the subtracted difference between the two times:

time to first hit = time of first hit minus time of start fire

2. DIMENSION OF THE MEASURE: interval -- an elapsed time in minutes The measure may be taken in ratio form, such as "mean time to first hit" or "expected time to first hit."

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of timeliness of firepower. It takes into account time to acquire, issue fire order, adjust and deliver fire, and correct for accuracy. Time is measured only to first hit because subsequent hits are not independent of the first hit.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative firing systems.

6. ASSOCIATED MEASURES:
   - Time to acquisition
   - Time to adjust
   - Time to completion
   - Rounds to adjust

7. REFERENCES:

ACN 06081 - Army Small Arms Weapon Systems Troop Acceptability Test
ACN 16914 - M60A1 Add-On Stabilization Troop Test, Apr 72
ACN 15961 - SHILLELAGH Field Experiment 11.6, Jun 69

MEAN ROUNDS TO FIRST HIT

1. DEFINITION OF THE MEASURE: Rounds to first hit is a number count of rounds fired from initiation of fire on a target to the first round on target. Input data are the number counts of rounds to first hit for each firing, and the number of firings. Relation of output to input is:

$$\text{mean rounds to first hit} = \frac{\sum^{n} (\text{nr rounds to first hit each firing}}{\text{nr firings}}$$

2. DIMENSION OF THE MEASURE: ratio -- an arithmetic mean in terms of mean number of rounds

3. LIMITS ON THE RANGE OF THE MEASURE: The measure has a weakness if there is any possibility that a target is not hit at all during the firing. Otherwise, the output value can be any positive integer. The larger the number of firings is, the more useful the output value.

4. RATIONALE FOR THE MEASURE: The measure addresses aspects of timeliness and accuracy of firepower, and takes into consideration ammunition expenditure. The measure seems more applicable to an engagement situation with both sides attempting to obtain the first killing hit.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate a firepower system in circumstances where the first killing hit is to be obtained as soon as possible. This is typical of tank-antitank engagements and aircraft- antiaircraft engagements.

6. ASSOCIATED MEASURES:

Time to first fire	Probability of hit
Time to first hit	Exposure time

7. REFERENCES:

ACN 16914 - M60A1 Add-On Stabilization Troop Test, Apr 72
ACN 17419 - Employment of Attack Heliocopters to Defeat Armor Study, Apr 71
ACN 15961 - SHILLEAGH Field Experiment 11.6, Jun 69

MEAN TIME TARGET ENGAGED

1. DEFINITION OF THE MEASURE: Mean time target engaged is the arithmetic average of the time periods a target is under fire. Input data are the start and end times of each firing on target. Relation of output to input is:

$$\text{mean time target engaged} = \frac{\sum^{n} (\text{each end time minus each start time})}{\text{number of elapsed times target under fire}}$$

2. DIMENSION OF THE MEASURE: Ratio -- An average time in seconds, minutes, and hours as appropriate.

3. LIMITS ON THE RANGE OF THE MEASURE: Theoutput may assume any positive value. The usefulness of the measure increases as the number of firings in the denominator increases.

4. RATIONALE FOR THE MEASURE: This measure addresses the effectiveness of a firepower system in terms of its sustained ability to keep a target under fire. The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative firepower systems in sustainability of effective fire. It would ordinarily be used in conjunction with other measures such as casualties inflicted and reaction times.

6. ASSOCIATED MEASURES:

Time to first fire	Loss exchange ratio
Casualties inflicted	Ammunition expenditure

7. REFERENCES:

ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75 - 15 Aug 67

AVERAGE TIME FIRING ON MOVING TARGET

1. DEFINITION OF THE MEASURE: Average time firing on moving target is the arithmetic mean of elapsed time from each start of fire to time that the last element of the moving target has moved a specified distance. Input data are time of first round on target and time last vehicle clears the distance. Relation of output to input is:

$$\text{average time firing} = \frac{\sum^{n} (\text{each elapsed time: first round to target clearing area})}{\text{number moving targets}}$$

2. DIMENSION ON THE MEASURE: ratio -- an average, in terms of average time in seconds and minutes

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. The distance to be cleared must be specified in keeping with the nature of the firing. In reference ACN 18288 the firing was an artillery fire mission, the target was a moving column of vehicles, and the specified distance was for the last vehicle to move 200 meters.

4. RATIONALE FOR THE MEASURE: This measure addresses the efficiency of firing on a moving target. It is a measure of how long the target is kept under fire which is presumed to be related to the amount of firing damage that can be done.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative systems of delivering fire on a moving target, for example, a procedure for acquiring an artillery target and calling and adjusting fire.

6. ASSOCIATED MEASURES:

- Mean rounds on target
- Mean error
- Time to acquisition
- Time to first fire

7. REFERENCES:

ACN 18288 - Artillery Versus Moving Target Follow-On (REACT) Field Experiment 32.2 , Jul 72

ACN 17271 - Ability to Adjust Arty on Moving Material Tgts Fld Expt 32.1

RATE OF TARGET DESTRUCTION

1. DEFINITION OF THE MEASURE: Rate of target destruction is the proportion of attacked target destroyed per specified time period. Input data are the size of the target, amount of target destroyed, start of attack time, and end of attack time. Relation of output to input is:

$$\text{rate of target destruction} = \frac{\dfrac{\text{amount of target destroyed}}{\text{size of target}}}{\text{end attack time minus start time}}$$

2. DIMENSION OF THE MEASURE: ratio -- a quotient in the form of a rate. Output is in terms of proportion per time period, for example, "five percent target destruction per minute."

3. LIMITS ON THE RANGE OF THE MEASURE: The output value may vary from zero to the total size of the target. Since a rate may change with time, the output value cannot be dissociated from the time period during which the measure was taken.

4. RATIONALE FOR THE MEASURE: The measure address amount of destruction directly, and goes on to combine it with time for a more refined measure. Furthermore, since the amount of destruction is limited to 100%, the measure allows a projection beyond the output value itself.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate firepower systems, or if firepower is held constant it can evaluate the resistance of the target.

6. ASSOCIATED MEASURES:
   - Percent target destruction
   - Casualty rate
   - Time to completion

7. REFERENCES:

No ACN- "Candidate Measures of Effectiveness for Air Strike Systems", Naval Weapons Center #TP 4687, Sep 69

ROUNDS TO COMPLETION

1. DEFINITION OF THE MEASURE: Rounds to completion is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit). Input data are the number of rounds to completion.

2. DIMENSION OF THE MEASURE: interval -- number count of rounds

3. LIMITS ON THE RANGE OF THE MEASURE: Output value may be any positive integer

4. RATIONALE FOR THE MEASURE: This measure addresses both timeliness of firepower and resources required.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate effectiveness of weapons systems firepower, command and control of fire, or expenditure requirements.

6. ASSOCIATED MEASURES:
   - Time to first hit
   - Time to completion
   - Rounds expended

7. REFERENCES:
   - ACN 06081 - Army Small Arms Weapon Systems Troop Acceptability Test

PROBABILITY OF HIT

1. DEFINITION OF THE MEASURE: Probability of hit (P_H) is the theoretic chance of hitting a target under stated circumstances if all unstated circumstances are random variables. The effect of stated circumstances is obtained by empirically observing the number of hits out of number attempts. Input data is either this quotient, or if hits data is available as a probability density function (number of hits for each value of another variable) the probability is the integral of the function for a given value of the other variable. Relation of output to input, then, is either:

$$P_H = \frac{\text{number hits}}{\text{number attempts}} \quad \text{or,} \quad P\left\{H\right\} = \int_{-\infty}^{H} P\left\{x\right\} dx$$

2. DIMENSION OF THE MEASURE: Ratio -- a probability is essentially the quotient of favorable outcomes (hits) divided by all possible outcomes (attempts)

3. LIMITS ON THE RANGE OF THE MEASURE: Probability values vary from zero to unity. The measure is not meaningful until the number of attempts is sufficiently large to represent the number of possible outcomes. When the integral is computed it is necessary to have the number of hits ordered by another variable and to have a sufficient representation at all levels.

4. RATIONALE FOR THE MEASURE: The measure indicates the liklihood of a hit under stated circumstances, which has direct military relevance. When a measure is taken in this form, probabilities can be combined in keeping with well-established rules of computing dependent and independent probabilities.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually applied to evaluations of a firepower system to compare systems, determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits. It can be used to compare firepower systems.

6. ASSOCIATED MEASURES:

Percent rounds hitting	Rounds to first hit
Percent targets hit	Probability of kill

7. REFERENCES:

ACN M1144, Army Aircraft Survivability Field Experiment 63.6
ACN 13105, XM - 19 Field Experiment 21.9, Jun 72
ACN 15961, SHILLELAGH Field Experiment 11.6, Jun 69
ACN 16914, M60A1 Add-On Stabilization Test, Apr 72
ACN 17494, Divisional War Game Model, Dec 71

PROBABILITY OF KILL

1. DEFINITION OF THE MEASURE: Probability of kill (P_k) is the theoretic chance of killing a target under stated circumstances if all unstated circumstances are random variables. The input data are the observed number of kills out of number of attempts. Relation of output to input is basically:

$$P_k = \frac{\text{number kills}}{\text{number hits}}$$

but may be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

2. DIMENSION OF THE MEASURE: Ratio -- A probability is essentially the quotient of favorable outcomes (kills) divided by all possible outcomes (attempts).

3. LIMITS ON THE RANGE OF THE MEASURE: A probability may assume any value from zero to unity. The measure improves as the size of the sample (number of attempts) increases.

4. RATIONALE FOR THE MEASURE: The measure indicates the likihood of a kill under certain circumstances, which has a direct military relevance. It is usually applied to determine the expected number of kills or expected chance of survival.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as expected number of kills, rounds required to kill, or probability of survival.

6. ASSOCIATED MEASURES:

Probability of hit
Number losses inflicted
Probability of survival
Loss exchange ratio

7. REFERENCES:

ACN M1144, Army Aircraft Survivability Field Experiment 63.6
ACN 12757, Secondary Armament for the MBT-70
No ACN - Land Combat System-I Study
No ACN - System Effectiveness Status Report, PERSHING
No ACN - "Candidate MOE for Effectiveness of Air Strike Systems," Naval Weapons Center Document #TP 4687

PERCENT ROUNDS HIT

1. DEFINITION OF THE MEASURE: Percent rounds hit is the percentage of all rounds fired that result in hits on target. Input data are number of rounds fired and number of rounds hitting. Relation of output to input is:

$$\text{percent rounds hit} = \frac{\text{number of hits}}{\text{number of rounds fired}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of rounds.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can vary from zero to one hundred percent. The value of the output is a function of the circumstances surrounding firing and can not be dissociated from the conditions of the firings.

4. RATIONALE FOR THE MEASURE: This is a direct measure of accuracy of fire. It is not quite as refined a measure as circular error probable or probability of hit, but requires less expensive measurement.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure, like probability of hit, is an indication of accuracy of firepower. It may be used to compare firepower systems in effectiveness.

6. ASSOCIATED MEASURES:
   - Probability of hit
   - Circular error probable
   - Percent targets hit

7. REFERENCES:
   - ACN M3523, Small Arms Weapons Systems (SAWS) - May 66
   - ACN 00983, Armor Units Limited Visibility Operations Troop Test - Jul 65
   - ACN 15961, SHILLELAGH Field Experiment 11.6, Jun 69
   - ACN 16975, Airborne STANO Systems Test, Part II
   - ACN 16914, M60A1 Add-On Stabilization Troop Test - Apr 72

PERCENT NEAR MISSES

1. DEFINITION OF THE MEASURE: Percent near misses is either the percentage of rounds that are near misses or the percentage of targets that are near misses. Near misses are rounds within a specified distance of the target that do not hit the target, usually measured by sound instrumentation. Relation of output to input is:

$$\text{percent near misses} = \frac{\text{number near misses}}{\text{number rounds (or targets)}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of percentage of total rounds or total targets.

3. LIMITS ON THE RANGE OF THE MEASURE: The output could vary from zero to one hundred percent. The distance to be counted as a near miss must be defined. In reference ACN M3523 it was defined as two meters.

4. RATIONALE FOR THE MEASURE: Near misses are thought of as a suppressive effect. They might also be thought of as a secondary guage of accuracy of fire in the sense that a system with a high percentage of near misses is more accurate than one with more outright misses, when percent hits is equal.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is not usually used alone, but in conjunction with hits. A system that has a higher percentage of near misses, as well as an adequate level of hits, has a suppressive effect and could be expected to have a higher percentage of hits against larger targets.

6. ASSOCIATED MEASURES:
   - Percent hits
   - Number hits
   - Circular error probable
   - Percent targets hit
   - Casualties inflicted

7. REFERENCES:

ACN M3523, Small Arms Weapons Systems (SAWS) Field Experiment 65.4 - May 66

MEAN OFFSET ERROR

1. DEFINITION OF THE MEASURE: Mean offset error is the arithmetic average of all errors, taken as distance from true location and taking direction into account. When errors are beyond the location values are positive, and shortfalls are negative. Errors in other directions are treated as positive or negative as appropriate. Input data are the error distance with signs. Relation of output to input is:

$$\text{mean offset error} = \frac{\sum^{n}(\text{each offset distance, true location to reported location})}{\text{number of reported location}}$$

2. DIMENSION OF THE MEASURE: Ratio -- An arithmetic mean. Output is in terms of a distance in inches, meters, or kilometers as appropriate.

3. LIMITS ON THE RANGE OF THE MEASURE: The denominator must be large enough to average out chance differences in error under the circumstances. The output value is representative only of the conditions under which it was derived and can not be dissociated from the stated conditions. Resolution is limited to the preciseness of the measure. The output may assume any finite positive or negative value.

4. RATIONALE FOR THE MEASURE: This measure addresses accuracy of location directly. Its main advantage is that it states a central tendency of error. It provides a usable summary of the degree of error. It is better than mean error (which is always positive) in those cases where overages and underages compensate for each other.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in the evaluation of any system that includes accuracy of locating points, and at the same time has the characteristic that positive and negative errors tend to cancel each other. For example, it can be used to compare accuracy of two systems in range estimation since overestimates and underestimates tend to cancel.

6. ASSOCIATED MEASURES:

Percent correct location
Mean error
Circular error probable

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70.
ACN 15961, SHILLELAGH Field Experiment 11.6, Jun 69.
ACN 02874, Troop Test: Overall Effectiveness of Artillery Organizations, Doctrine and Concepts, Aug 65

CIRCULAR ERROR PROBABLE (CEP)

1. DEFINITION OF THE MEASURE: Circular error probable is the length of the radius from center of target of a circle that includes 50% of all observed locations. It is based on the observed natural dispersion of errors about the center, which shows most errors are small and grouped closely around the center, and larger errors are rarer. Input data are the measured lengths of the offset distance of each error from target center. (This measure is sometimes called median offset error). That is, the CEP is the distance from center exceeded by one half of the misses. Relation of output to input is the median of all miss distances, or can be computed by:

$$CEP = 1.774\left[\sqrt{\frac{1}{n}\text{ (sum of distance of all misses)}}\right]$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is in terms of a distance from true center, in terms of inches, meters, kilometers, or any appropriate unit of measure for distance, and its value rests on a computation based on random error distribution.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is limited to the circumstances in which a normal distribution of misses can be expected. In general, this means there must be no systematic bias in misses, that all observations are offset by a combination of ordinary random errors. The measure is not meaningful for small numbers of observations, and becomes more useful as the number of observations increases.

4. RATIONALE FOR THE MEASURE: The rationale depends on an observed natural law of random errors, that they are distributed in keeping with a normal Gaussion distribution. When this law is applicable, any measure based on the distribution would be possible.

5. DECISIONAL RELEVANCE OF THE MEASURE: CEP is useful in two commonly used contexts.

a. Firing accuracy. CEP is often used to measure the accuracy of fire of a firing system ranging from a single weapon shot pattern to accuracy of strategic missiles of bombing.

b. Location accuracy. CEP can also be applied to the accuracy of locating a target in the target acquisition process. In this case the offset error is the difference between reported location and true location.

6. ASSOCIATED MEASURES:

Mean offset error	Proportion of hits to rounds
Probability of hit	Proportion of correct locations

7. REFERENCES:

ACN 17271, Ability to Adjust Artillery Fire on Moving Materiel Field Experiment 32.1

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70

ACN 18288, Artillery Versus Moving Targets Follow-On (REACT), - Jul 72

ACN 17781, Precision Position Locator System Field Experiment 42.9 Jun 71

NO ACN Systems Effectiveness Report (PERSHING), - Feb 72

MILITARY WORTH INDEX

1. DEFINITION OF THE MEASURE: Military worth index is a combination of the probability of inflicting damage and the value of the damage that can be inflicted by a weapons system. Input data are the probability of defeating each target (P_d) and military worth (W) of each target that can be defeated. Probability of target defeat is a function of targets destroyed for targets presented, and military worth is any assessment of target value, such as number of personnel, vehicles, or weapons. Relation of output to input is:

$$\text{military worth index} = \sum_{i=1}^{n} \left[W_i \cdot P_{d_i} \right]$$

2. DIMENSION OF THE MEASURE: index number -- a type of utility value. Output is in terms of total probable value of destruction.

3. LIMITS ON THE RANGE OF THE MEASURE: It is quite often difficult to assign military worth to different types of targets because a common denominator must be delineated. (In one of the referenced studies values were assigned by a consensus of judgments). The output can assume any value up to the total of the assigned military worth values, and would ordinarily be some fraction of this total.

4. RATIONALE FOR THE MEASURE: The intent of this measure is to take into account not only the effectiveness of the weapons system in inflicting damage but also the importance of the targets damaged. The significant aspect of the measure is to account for differences in priority of targets defeated.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate weapons systems.

6. ASSOCIATED MEASURES:
   - Probability of kill
   - Casualty rate
   - Loss exchange ratio
   - Probability of success

7. REFERENCES:

   - ACN 15724, Optimum Mix of Artillery Units (1975-1980)
   - ACN 07346, Optimum Mix of Artillery Units (1971-1975)
   - ACN 13138, Divisional Artillery Study
   - ACN 13708, TACFIRE Cost Effectiveness Study
   - ACN 06488, Artillery (1970-1975)
   - ACN 03434, Lance Cost-Effecciveness Study

FIREPOWER POTENTIAL (POINT FIRE WEAPONS)

1. DEFINITION OF THE MEASURE: Firepower potential for point fire weapons is the product of average kill probability $\left(\frac{PM}{ER}\right)$, range (R), and ammunition expenditure (AE). Average kill probability is the integral of single shot effective range (ER). Relation of output to input is:

$$\text{Firepower potential} = \left(\frac{PM}{ER}\right) (R)\ (AE)$$

2. DIMENSION OF THE MEASURE: index number -- the output is a value of average kill probability for given range and expenditure

3. LIMITS ON THE RANGE OF THE MEASURE: Since an average kill probability over all ranges is part of the computation, the index depends on firing being done at maximum effective ranges. The range value (R) cannot be a simple range but must be a transform that gives greater value to shorter ranges (for example, the reciprocal of range). Number of rounds fired is treated multiplicatively, which ignores lack of independence between rounds.

4. RATIONALE FOR THE MEASURE: An index number of this sort is useful in combining the effects of various point fire weapons, each in consideration of its own range limitations.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to be used in comparisons of systems involving several types of point fire weapons.

6. ASSOCIATED MEASURES:
   - Firepower potential (area fire weapons)
   - Probability of hit
   - Probability of kill

7. REFERENCES:

Measuring Combat Effectiveness, Vol I, Firepower Potential, USACDCISS

FIREPOWER POTENTIAL (AREA FIRE WEAPONS)

1. DEFINITION OF THE MEASURE: Firepower potential for area fire weapons is the product of mean lethal area and ammunition expenditure (AE). Mean lethal area is average lethal area of each type of ammunition and the fraction of each type that comprises the basic load. Input data are the number of rounds fired (AE), lethal area of each type of weapon (LA_i), and fraction of the total basic load (T) for each type $\left(\frac{L_i}{T}\right)$. Relation of output to input is:

$$\text{firepower potential} = (AE)\,(LA_i)\left(\frac{L_i}{T}\right)$$

2. DIMENSION OF THE MEASURE: index -- the output is an index number indicating expected lethal area for a given basic load and expenditure.

3. LIMITS ON THE RANGE OF THE MEASURE: Since an average lethal area is part of the computation, the index is an arithmetic expectation subject to distortion for unusual conditions. Number of rounds fired is treated multiplicatively ignoring the lack of independence between rounds. Average lethal area may be a difficult input to obtain.

4. RATIONALE FOR THE MEASURE: The index is actually a computation for a given amount of firing with a certain average lethal area. In this sense it is a direct calculation of potential firepower.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to be used to compare alternative area fire weapons systems.

6. ASSOCIATED MEASURES:
   - Firepower potential (point fire weapons)
   - Probability of hit
   - Probability of kill

7. REFERENCES:

Measuring Combat Effectiveness, Vol. I, Firepower Potential, USACDCISS

WEAPON FRACTIONAL KILL VALUE

1. DEFINITION OF THE MEASURE: Weapon fractional kill value is defined as the fraction of the enemy force it destroys. Input data are number count of enemy initial size and number count of enemy losses to considered weapon. Relation of output to input is:

$$\text{weapon fractional kill value} = \frac{\text{number of enemy losses inflicted}}{\text{initial number of enemy}}$$

2. DIMENSION OF THE MEASURE: Ratio -- fraction of enemy force destroyed.

3. LIMITS ON THE RANGE OF THE MEASURE: The fraction may vary from zero to unity. Its usefulness is limited by its applicability to only a single initial force size and only a single time period.

4. RATIONALE FOR THE MEASURE: One possible assignment of value to a weapon is the amount of destruction it accomplishes. This can be extended to take different weapons into account by making the initial force size a common denominator for the various weapons.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is not intended for comparisons by itself. It is intended mainly as a value to be used in more complex measures for assignment of values to weapons. (Probability of kill is a more flexible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.

6. ASSOCIATED MEASURES:
   - Probability of kill
   - Firepower potential
   - Loss exchange ratio
   - Force Effectiveness Indicator (FEI)

7. REFERENCES:
   - ACN 17018, Antitank Weapons Systems Requirements Study

EXPECTED REMAINING TANK KILLING CAPABILITY

1. DEFINITION OF THE MEASURE: Expected remaining tank killing capability is the computation of utility value at a given point in time taking into account both the expected remaining force size and the killing capability of that force size. It is the sum of the probability of kill of weapon a times the expected remaining number of weapons a, plus the same utility value for weapon b, and so forth, to weapon n. Input values are the separately computed probability of kill (P_k) and expectation of survival (Es) for each weapon. Relation of output to input is:

expected remaining tank killing capability = $(Pk_a)(Es_a) + (Pk_b)(Es_b)\ldots(Pk_n)(Es_n)$ Pk_a is separately computed as the proportion of kills per attempt, and Es_a is computed as proportion of force size remaining at a given time.

2. DIMENSION OF THE MEASURE: Computed potential -- the unit of output measure is the tank killing potential at a given time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output varies from zero to any positive measure up to the number of weapon systems (n) considered. All values of Pk and Es are between 0 and 1.0 inclusive.

4. RATIONALE FOR THE MEASURE: The measure is primarily concerned with survivability but goes beyond expected remaining force size to also take into account the utility value of the remaining force size in terms of its killing capability. The measure includes in itself the weighting for values of kill and number of weapons remaining.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is especially useful in combining the effects of different weapons with the same mission. In the referenced study it was considered a cogent combination of survivability and productivity. It is noted that the measure need not be limited to antitank weapons. It could as easily be expected remaining personnel killing capability, or expected remaining aircraft killing capability.

6. ASSOCIATED MEASURES:
   - Probability of kill
   - (Any survivability measure)
   - Average number of tanks killed

7. REFERENCES:

ACN 17018, Antitank Weapons Systems Requirements Study

PERCENT AVENUES OF APPROACH COVERED

1. DEFINITION OF THE MEASURE: Percent avenues of approach covered is the percentage of enemy avenues of approach that are covered by the appropriate weapons, for example armor avenues of approach covered by anti-armor weapons. Input data are number of avenues of approach and number of these avenues covered. Relation of output to input is:

$$\text{percent avenues of approach covered} = \frac{\text{number avenues covered}}{\text{total number avenues}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage.

3. LIMITS ON THE RANGE OF THE MEASURE: Output value may vary from zero to one hundred percent. The criterion for being "covered" must be defined. This measure is relatively crude in that it does not take into account multiple coverage of an avenue or range of the covering weapons. A more refined measure would be the mean number of weapons per avenue, or an even more refined measure would be average meters multiple coverage.

4. RATIONALE FOR THE MEASURE: The measure directly addresses the amount of potential firepower in one aspect of firepower.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure could be used to evaluate a defensive tactic, a proposed organization or a command and control system. Alternatively it might be used in computing potential firepower.

6. ASSOCIATED MEASURES: Area coverage
Probability of hit

7. REFERENCES:
No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

SMALL ARMS AIR DEFENSE POTENTIAL

1. DEFINITION OF THE MEASURE: Small arms air defense potential is a computation of the theoretic kill capability against light aircraft as a function of vulnerable area of the aircraft, projectile weight, and striking velocity. Striking velocity is a function of slant range. Relation of output to input is:

$$\text{Small arms AD potentional} = \frac{\text{vulnerable area of aircraft}}{\text{projectile weight X striking velocity}}$$

2. DIMENSION OF THE MEASURE: Index number -- a computation resulting in a pure number related to the probability of kill given a hit. May be any positive number and is limited only by the values used for the three inputs, which would usually be in square meters of vulnerable area, grams weight, and feet per second striking velocity.

3. LIMITS ON THE RANGE OF THE MEASURE: The number derived is useful only in the context observed. It ignores probability of hit and other factors in probability of kill. The number derived cannot be disassociated from the conditions under which it was derived, so it can only be compared to itself.

4. RATIONALE FOR THE MEASURE: This is a fairly simple index number for assigning air defense potential to small arms in comparison with each other. It ignores several factors necessary to computation of the superior measure (probability of kill) but is easier to collect data for than the superior measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: Can be useful in comparing small arms on air defense potential when air defense is a secondary, relatively less important mission. When air defense is not a primary mission this is a useful supplementary measure of small arms materiel effectiveness.

6. ASSOCIATED MEASURES:
   - Probability of (air defense) kill
   - Probability of hit
   - (any fire potential measure)

7. REFERENCES:
   - ACN 03498, Small Arms Weapons System Study

MOBILITY

MARCH RATE

1. DEFINITION OF THE MEASURE: March rate is the distance covered by a unit per time interval. Input data are amount of distance traveled and elapsed time. Relation of output to input is:

$$\text{march rate} = \frac{\text{distance traveled (in meters, kilometers, or other)}}{\text{elapsed time (in minutes, hours, or days)}}$$

Alternatively, if the input data is in the form of cumulative distance as a function of time, the rate may be computed as the first derivative.

2. DIMENSION OF THE MEASURE: ratio -- in terms of meters per hour, kilometers per day, or as appropriate

3. LIMITS ON THE RANGE OF MEASURE: The output value is zero or any positive distance per time perios. The usefulness of the measure increases as the amount of time in the denominator increases. The rate may change, so the output value cannot be dissociated from the time actually observed.

4. RATIONALE FOR THE MEASURE: This measure addresses the timeliness aspect of maneuverability.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is useful for any evaluation of maneuverability.

6. ASSOCIATED MEASURES:
   - Rate of advance
   - Area coverage
   - Percent moves completed in time
   - Distance to objective

7. REFERENCES:
   - ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75 Field Experiment 65.1, 15 Aug 67
   - ACN 17494 - Divisional War Game Model, Dec 71
   - ACN 13233 - Land Navigation Systems Troop Test, Jul 70

PERCENT MOVES WITHIN TIME

1. DEFINITION OF THE MEASURE: Percent moves within time is the percentage of ordered moves that are completed by the time ordered. Input data are the number of moves and the number of these arriving within the time ordered. Relation of output to input is:

$$\text{percent moves within time} = \frac{\text{number of moves completed by time ordered}}{\text{total number of moves}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of all moves

3. LIMITS ON THE RANGE OF THE MEASURE: Output may vary from zero to one hundred percent. The measure is diluted somewhat by moves which have no completion time (such as ASAP moves) all of which are on time by definition.

4. RATIONALE FOR THE MEASURE: This measure addresses timeliness of mobility in a militarily relevant manner. A more refined form of the measure is "percent delay" in which the mean time of delay in completing each move is divided by the time required for the move.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate a mobility system. It has at least three possible applications:

(a) In ACN 16818 it was used to compare material systems.
(b) In ACN 06930 it was used to evaluate a proposed doctrine that had difficulties in mobility.
(c) It has been used to evaluate training.

6. ASSOCIATED MEASURES:
March rate
Percent delay

7. REFERENCES:

ACN 16818, STANO I Test, Dec 69
ACN 06930, Troop Test Frontier Shield, Feb 67
No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PERCENT UNIT AT PRESCRIBED INTERVAL

1. DEFINITION OF THE MEASURE: Percent unit at prescribed interval is the percentage of all elements (personnel, vehicles, or subordinate units as appropriate) at the prescribed interval for march. Input data are the number of elements and the number of these at the prescribed interval from any other element. Relation of output to input is:

$$\text{percent unit at prescribed interval} = \frac{\text{number elements at prescribed interval}}{\text{number elements in move}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of personnel, vehicles, or subordinate units

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. The tolerance limit for deviation from the prescribed interval must be established. This is a comparatively unrefined measure. It could be made more refined by computing the mean deviation from prescribed interval and dividing this by the interval ordered as a measure of "percent mean deviation from prescribed interval."

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of a mobility system. Variation in actual interval is presumed to be one of the most sensitive indicators of difficulty in mobility. Whether the deviations come from problems in terrain, tactical action, training, or command and control they are a measure of mobility effectiveness.

6. ASSOCIATED MEASURES:
   Percent moves within time
   March rate

7. REFERENCES:
   ACN 16818, STANO I Test, Dec 69

TIME TO CHANGE FORMATION

1. DEFINITION OF THE MEASURE: Time to change formation is the elapsed time required to change a moving unit from one formation to another. Input data are the start and end times of making the change. Relation of output to input is the subtracted difference:

time to change formation = end time of change minus start time

2. DIMENSION OF THE MEASURE: Interval -- Output is in terms of seconds, minutes, and hours. The measure could be taken in ratio form, such as mean time or expected time, if data from several changes are available.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be any positive value. Since the value is a function of the size and type of unit involved, the terrain and tactical situation, and the beginning and ending formation, the value can not be dissociated from the conditions under which it was derived.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of command and control. Part of the function of control is to change formations while moving, and the efficiency of such changes can be indicated by the time required.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative systems relating to command and control.

6. ASSOCIATED MEASURES:
   - Order dissemination time
   - Percent messages received
   - Time to execute order

7. REFERENCES:

ACN 3067, Infantry Rifle Unit Study (IRUS) - Jul 69

PERCENT DELAY

1. DEFINITION OF THE MEASURE: Percent delay is the amount of delay in completing a move as a percentage of the total time to complete the move. Input data are the start time (S), ordered completion time (O), and actual completion time (A). Relation of output to input is:

$$\text{percent delay} = \frac{(A - S) - (O - S)}{(O - S)} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is a percentage, in terms of percent of planned time.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any value from negative one hundred percent to positive infinity.

4. RATIONALE FOR THE MEASURE: This measure addresses timeliness of mobility, taking into account how timely.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to evaluate a mobility system.

6. ASSOCIATED MEASURES:
   - Percent moves completed in time
   - Mean time to negotiate obstacles

7. REFERENCES:
   None - this is a potential measure

MEAN TIME TO NEGOTIATE OBSTACLES

1. DEFINITION OF THE MEASURE: Mean time to negotiate obstacles is the arithmetic average of each elapsed time consumed in overcoming an obstacle to advance. Input data are the delay time for each obstacle and the number of obstacles. Relation of output to input is:

$$\text{mean time to negotiate obstacles} = \frac{\sum^{n} (\text{each elapsed obstacle delay time})}{\text{number obstacles}}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a mean time in hours and minutes

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. As it is stated the measure makes no distinction among different types of obstacles. It would probably be better to break it down into measures for river crossings, minefields, barriers, barbed wire, and so forth.

4. RATIONALE FOR THE MEASURE: This measure addresses mobility performance in terms of times to negotiate obstacles based on the premise that shorter negotiation delay times mean better mobility.

5. DECISIONAL RELEVANCE OF THE MEASURE: Since this is a measure of performance rather than a true measure of effectiveness, it is applied to comparing mobility systems under the same conditions. It could be converted to a measure of effectiveness by taking total move time into account with obstacle delay time as "percent delay", assuming that zero delay for obstacles is ideal performance.

6. ASSOCIATED MEASURES:
   - Percent delay
   - March rate
   - Percent moves completed on time

7. REFERENCES:

ACN 06930, Troop Test Frontier Shield, Feb 67

PERCENT FORCE COMPLETE MOVE

1. DEFINITION OF THE MEASURE: Percent force complete move is the percentage of a force starting a move that arrives at the destination. In the case of an attack movement, it is the percentage of force surviving at the objective. Input data are the initial size of the force (number of personnel, vehicles, aircraft, subordinate units, or as appropriate), and the size of the force arriving at destination. Relation of output to input is:

$$\text{percent force complete move} = \frac{\text{number arriving}}{\text{number starting}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a percentage in terms of percent of initial force size.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. It is necessary to establish a convention for elements of the force which arrive at the destination separate from and later than the main arrival.

4. RATIONALE FOR THE MEASURE: This measure addresses mobility effectiveness in respect to the amount of planned movement accomplished. It can be used for mobility difficulties such as terrain, tactical action, command and control problems, or training.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate a mobility system.

6. ASSOCIATED MEASURES:
   - March rate
   - Percent delay
   - Percent moves completed within time

7. REFERENCES:
   - ACN 06930, Troop Test Frontier Shield - Feb 67
   - No ACN, Reserve Components Revised ATT, USCONARC - Mar 72

CLOSING TIME

1. DEFINITION OF THE MEASURE: Closing time is the elapsed time between the first and last arrival at destination or rendevous point. Input values are the moments of arrival of the first and last element of the unit. Elements might be personnel, vehicles, subordinate units, or other appropriate element. Relation of output to input is:

closing time = arrival of last element minus arrival of first element

2. DIMENSION OF THE MEASURE: Interval -- Output is a chronological elapsed time in hours, minutes and seconds. The measure may be taken in ratio form, such as mean time, if several observations are made.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive value. Since the value is a function of the type and size of unit, terrain and tactical situation, and other factors, the value can not be dissociated from the conditions under which it was derived. In addition, a convention must be established for elements which fail to join the unit at all.

4. RATIONALE FOR THE MEASURE: This measure addresses one aspect of command and control, that part of control concerning the ability of a command to move its elements at various speeds to meet a preset schedule.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare alternative control systems. Or under some circumstances it may be used to evaluate mobility.

6. ASSOCIATED MEASURES:
   Movement rate
   Percent messages received
   Time to execute order

7. REFERENCES:
   ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75 - Jul 69

INTELLIGENCE

PROPORTION TARGETS DETECTED

1. DEFINITION OF THE MEASURE: Proportion targets detected is the quotient of number of targets detected divided by the number of potential targets. Potential targets is a number count of all targets in the area of operations. Relation of output to input is:

$$\text{proportion targets detected} = \frac{\text{number of targets detected}}{\text{number of total potential targets}}$$

If the same target is detected more than once, only the initial detection is counted in this measure.

2. DIMENSION OF THE MEASURE: Ratio -- A quotient. The measure is also often used in the form of a percentage, "PERCENT TARGETS DETECTED."

3. LIMITS ON THE RANGE OF THE MEASURE: The output can vary from zero to unity (or from zero to one hundred percent). When a target is moving a rule has to be established for how often it becomes a "new" potential target.

4. RATIONALE FOR THE MEASURE: This measure addresses amount of detection directly, and is a primary measure of intelligence collection effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to compare intelligence collection systems. It is rarely used alone; it is usually used in conjunction with measures of timeliness and accuracy of detection.

6. ASSOCIATED MEASURES:

Probability of detection
Mean time to detection
Detections to targets ratio

7. REFERENCES:

ACN 06930, Troop Test Frontier Shield, May 66.
ACN 15353, Field Evaluation HIGH Gear, Jun 69 .
ACN 16975, Airborne STANO Systems Test.
ACN 14118, SEANITEOPS Ground Field Experiment 72.8, May 70.
ACN 12944, Exploratory Night Operations Field Experiment, Jun 68.
ACN 16782, System Assessment Model Technical Report 6-71, Oct 71.
ACN 17494, Divisional War Game Model, Dec 71.
ACN 16849, MASSTER II Test, Dec 70.
ACN 17036, MASSTER III Test, Oct 71.
No ACN, Candidate MOE for Air Strike Systems, Naval Weapons Center Report #TP 4687.
No ACN, MASSTER Improved Acoustic Locator Test, Mar 72.
ACN 16813/18668, ACCB/TRICAP Field Test Series.
ACN 17873, Airborne Company STANO Test.
ACN 18026, Armored Cavalry Troop STANO Test.
ACN 17050, Tank Company STANO Test.
ACN 17874, Mechaniz d Rifle Company STANO Test.
ACN 16818, STANO I Test, Dec 69.
ACN 16819, STANO II Test, Jul 69.

PROBABILITY OF DETECTION

1. DEFINITION OF THE MEASURE: Probability of detection is the proportion of detection to detection opportunities. When detection opportunities are simply totaled the output is computed as the quotient of detections divided by opportunities in the form:

$$\text{probability of detection} = \frac{\text{number of detections}}{\text{number of detection opportunities}}$$

When, however, the detections are arranged as a function of another variable (for example, as a density function of time) the probability is computed as an integral with respect to a given value, as in the form:

$$P\{x\} = \int_{-\infty}^{x} p(t)\,dt$$

2. DIMENSION OF THE MEASURE: Ratio -- Whether in the simplest form or in an integral with respect to another variable, probability is basically a ratio of detections to opportunities.

3. LIMITS ON THE RANGE OF THE MEASURE: Probability can vary from zero to unity, and the usefulness of the measure increases as the number of detection opportunities increases.

4. RATIONALE FOR THE MEASURE: Probability of detection is one of the most useful measures of detection effectiveness in that it is directly translatable into military application.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used in any evaluation in which the effectiveness of detection in an issue.

6. ASSOCIATED MEASURES:
   - Proportion of targets detected
   - Detection time to range ratio
   - Time to detection

7. REFERENCES:

ACN 7395, Ground Observer Probabilities of Acquisition and Adjustment Field Experiment 31.1 - Sep 68
ACN 03598, Radar Concept Field Experiment 65.5, Aug 65
ACN 18728, STANO Survey and Review (STASAR), Jul 71
ACN M1144, Army Aircraft Survivability Field Experiment 63.6
ACN 07769, ENVE Field Experimentation Series: Part I - 71.1, Sep 66; Part II, 72.9, Sep 68; Part III, 72.10, Dec 68.

PERCENT TRUE DETECTIONS

1. DEFINITION OF THE MEASURE: Percent true detections is the percentage of all reported detections that are confirmed as true detections. It is the complement of false detections. Input data are the number of reported detections and number of true detections. Relation of output to input is:

$$\text{percent true detections} = \frac{\text{number detections confirmed as valid}}{\text{number detections reported}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of percent of detections. May also assume the form of proportion of true detections, or fraction or ratio of true detections to all detections.

3. LIMITS ON THE RANGE OF THE MEASURE: The value of the measure increases as the size of the denominator increases. The output can assume any value from zero to one hundred percent, inclusive.

4. RATIONALE FOR THE MEASURE: This is a measure of detection capability. It addresses accuracy of detection as opposed to proportion of targets detected. It keeps a system from increasing number of detections by including a large proportion of false detections.

5. DECISIONAL RELEVANCE OF THE MEASURE: The MOE may be used in any situation where both amount and accuracy of detection are issues.

...URES:
targets detected
...tections

...NITEOPS Ground Field Experiment 72.8 - May 70.
...Exploratory Examination in Night Operations, Jun 68.
... ACN, MASSTER Improved Acoustic Locater System Test, Mar 72.
ACN 16782, Systems Assessment Model, Oct 71.
ACN 10784, Troop Test REDEYE, 1967

PERCENT FALSE DETECTIONS

1. DEFINITION OF THE MEASURE: Percent false detections is the percentage of all reported detections that are not confirmed as actual true detections. It is the complement of percentage of true detections. Input data are the number of reported detections and the number of reported detections confirmed as true detections. Relation of output to input is:

$$\text{percent of false detections} = \frac{\text{total reported detections minus true detections}}{\text{total reported detections}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of percentage of false detections to all detections (e.g., 10% false detection). Alternative forms are proportion of false detections (e.g., 0.10 false detections) or fraction (e.g., 21/210 false detections).

3. LIMITS ON THE RANGE OF THE MEASURE: The usefulness of the measure increases as the size of the denominator increases. Output can assume any value from zero to one hundred percent inclusive.

4. RATIONALE FOR THE MEASURE: This measure addresses accuracy of detection. It puts a check on measuring effectiveness of detection by amount and timeliness of detection without considering accuracy.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure can be used to compare alternative candidates in any evaluation where accuracy of detection is part of the example. In the referenced study it was used to further rate candidate night operations devices which were roughly equal in amount of detection partly because one candidate achieved a higher level of detection by including more false detections.

6. ASSOCIATED MEASURES:
   - Percent targets detected
   - Percent true detections
   - Time to detection

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70.
ACN 15353, Field Evaluation HIGH GEAR, Jun 69.
ACN 16818, STANO I Field Evaluation, Dec 69.
ACN 10784, Troop Test REDEYE, 1967

PERCENT FALSE DETECTIONS CORRECTED

1. DEFINITION OF THE MEASURE: Percent false detections corrected to the percentage of reported detections not confirmed as true detections that are corrected. In this case correction is a withdrawal or change of the detection report. Input data are total number of reported detections, detections confirmed as true, and detections withdrawn or changed. Relation of output to input is:

$$\text{percent false detections corrected} = \frac{\text{detections withdrawn or changed}}{\text{total detections reported minus true detections}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in the form of percentage of false detections corrected (e.g., 10% false detections corrected). Alternative forms are proportion (.10 false detections corrected) and fraction (21/210 of false detections corrected).

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is more meaningful as the total number of detections increases. The output may assume any value from zero to one hundred percent inclusive. The criterion for correction has to be defined, as for example, that the detection report is withdrawn before confirmation is complete, and the final value can not be dissociated from the definition.

4. RATIONALE FOR THE MEASURE: This measure is assumed to address accuracy of detection in the sense that a high percentage of correction of false detections is similar to a low percentage of false detections.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is suitable as one of several measures when comparing candidate systems in accuracy of detection. It has the effect of crediting the system with delayed accuracy. Usually a better measure would be time to (true) detection, but this measure may be useful when it is too costly to obtain time measures.

6. ASSOCIATED MEASURES:

- Percent targets detected
- Percent true detections
- Time to detection
- Percent false detections

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70

TIME TO DETECTION

1. DEFINITION OF THE MEASURE: Time to detection is the elapsed time from presentation of the target until detection of it. Input data are the moment of presentation and the moment of detection. Relation of output to input is:

Time to detection = time of detection - time of presentation

2. DIMENSION OF THE MEASURE: Interval -- an interval of time in terms of seconds, minutes or hours. If the measure is taken over time or across conditions, it can be used in the form of mean time to detection, or median time to detection.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can take the value of zero or any positive value. The refinement of the measure is limited by the preciseness of taking start times and end times. There is a practical problem in using the measure when the target is sometimes not detected at all.

4. RATIONALE FOR THE MEASURE: This measure addresses one of the most important components of target acquisition directly. It measures the effectiveness of search techniques and detection aids. Most problems in detection are assumed to contribute to lengthening detection time.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure can be used to compare detection means (techniques, aids, trained personnel) to each other or to a standard when all targets are finally detected. If less than all targets are detected, this measure can be a supplementary measure to refine grosser measures of detection.

6. ASSOCIATED MEASURES:

- Proportion of targets detected
- Probability of detection
- Exposure time
- Probability of kill
- Time to identification
- Time to estimate range

7. REFERENCES:

ACN 17617, BAHT Field Experiment 43.5, Feb 71
ACN 18171, Attack Helicopter - Daylight Defense Field Experiment 43.6
ACN 18837, OTE FAAR, Phase I, Apr 72
ACN 14118, SEANITEOPS Ground Field Experiment 72.8, May 70
ACN 07395, Ground Observer Probability of Acquisition Field Experiment 31.1, Sep 68
ACN 16782, Systems Assessment Model, Oct 71
ACN M1144, Army Aircraft Survivability Field Experiment 63.3, Jun 66
ACN 15961, SHILLELAGH Field Experiment 11.6, Jun 69

PERCENT OF TARGETS DETECTED IN TIME

1. DEFINITION OF THE MEASURE: Percent of targets detected in time is the percentage of all potential targets detected within a specified time for detection of the target type. Relation of output to input is:

$$\text{pct of tgts detected in time} = \frac{\sum^{n} \text{(tgts detected within time)}}{\text{nr potential tgts}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is in terms of a percentage.

3. LIMITS ON THE RANGE OF THE MEASURE: Usefulness of measure improves as number of potential targets improves. Only initial detections may be counted; subsequent detections of same target must be deleted. Output value may be 0% through 100%, inclusive.

4. RATIONALE FOR THE MEASURE: This measure is a convenient way of measuring the timeliness of detection when a criterion can be defined. While it is not as sensitive a measure as time-to-detection, it is much easier to measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used whenever timeliness of detection is an issue. In the referenced study it was used to determine whether a unit could meet target acquisition standards set by the Capabilities Requirements Statements (CRS).

6. ASSOCIATED MEASURES:
   - Time to detection
   - Probability of detection
   - Percent of targets detected

7. REFERENCES:
   ACN 17036, MASSTER III Systems Field Test

DETECTION RATE

1. DEFINITION OF THE MEASURE: Detection rate is the number of targets detected per time period, such as detections per hour or detections per day. Input data are the number of detections and the time measure. Relation of output to input is:

$$\text{detection rate} = \frac{\text{number of target detections}}{\text{elapsed time}}$$

2. DIMENSION OF THE MEASURE: ratio -- this is a measure of rate. In the form of detections as a function of time, the rate may be treated as the first derivative of the function.

3. LIMITS ON THE RANGE OF THE MEASURE: The usefulness of the measure increases as the length of time in the denominator increases, and the resolution of the measure is dependent on the refinement of the time measure. Since rate may change the output value cannot be dissociated from the time interval.

4. RATIONALE FOR THE MEASURE: This measure addresses both amount and timeliness of detection in what appears to be a meaningful combination.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to discriminate among detection systems that are equal in terms of simpler measures such as per cent of targets detected or time to detection. The data of this measure, handled cumulatively, leads to probability of detection as a function of time.

6. ASSOCIATED MEASURES:
    - Proportion of targets detected
    - Time to detection
    - Probability of detection

7. REFERENCES:
ACN 18728 - STANO Survey and Review (STASAR), 1971

DETECTION TIME TO RANGE RATIO

1. DEFINITION OF THE MEASURE: Detection time to range ratio is the quotient of time to detection divided by range at detection. In the referenced study the square of the range was used to take into account that a search for detection is an area search. Input data are time to detection in any chronological measure, and range from detector to target at moment of detection in any distance measure. Relation of output to input is:

$$\text{detection time to range ratio} = \frac{\text{time to detection}}{\text{range at detection (may be squared)}}$$

2. DIMENSION OF THE MEASURE: Ratio -- A quotient. Output is in terms of seconds per square meter, or other suitable time:distance expression.

3. LIMITS ON THE RANGE OF THE MEASURE: Output may assume any positive value. Resolution of the output depends on precision in measuring input.

4. RATIONALE FOR THE MEASURE: While detection time is usually a suitable measure in itself, this combined measure goes beyond simple timing to take into account that times should be greater when greater areas are searched.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is suitable in any comparison of detection systems, and is especially useful when the competing systems are not attempting to detect precisely the same targets.

6. ASSOCIATED MEASURES:

Time to detection
Range at detection
Percent targets detected

7. REFERENCES:

ACN 12944, Exploratory Examination in Night Operations Field Experiment 71.4 - Jun 68

RANGE OF DETECTION

1. DEFINITION OF THE MEASURE: Range of detection is the straight line distance from detector to target at moment of first detection. Input data are the location of the detector and the target. If there is a difference in elevation, such as when either the detector or the target is an aircraft, it is called the "ground range of detection". Relation of output to input is:

range of detection = difference between detector location and target location

2. DIMENSION OF THE MEASURE: Interval -- The output is a linear variable in the form of meters, kilometers, miles or other suitable unit of measure for distance.

3. LIMITS ON THE RANGE OF THE MEASURE: Resolution of the measure depends on the unit of measure of distance and preciseness of measures. Computation of input values may be complex if the two locations differ in two dimensions (such as two locations on a map) or three dimensions (such as aircraft and groundpoint), and especially if one or both are moving. Output may assume any positive value.

4. RATIONALE FOR THE MEASURE: This is considered one of the direct measures of effectiveness of detection. Ability to detect at greater range usually results in a higher proportion of targets detected and shorter time to detection.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable in any comparison of alternative detection means. In the referenced studies it was used to discriminate among detection systems targeted against moving threats (such as aircraft) that might or might not approach the detector.

6. ASSOCIATED MEASURES:

Proportion of targets detected	Time to detection
Percent true detections	Probability of detection

7. REFERENCES:

ACN 11670, Field Experiment 72.2 (Reduction of Noise Level of Operational Aircraft) - Dec 67
ACN 16819, STANO II Part I Test.
ACN 16849, MASSTER II Test.
ACN 17036, MASSTER III Test.

MEAN RANGE OF DETECTION

1. DEFINITION OF THE MEASURE: Mean range of detection is the arithmetic mean of all target detections. Input data is the distance from detector to target for each detection, in meters or other appropriate unit of measure of distance. Relation of output to input is:

$$\text{mean range of detection} = \frac{\sum^{n} (\text{each distance from detector to detected target})}{\text{number of detections}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Arithmetic average. Output is expressed in unit of distance, such as, meters or kilometers.

3. LIMITS ON THE RANGE OF THE MEASURE: Usefulness of measure improves as the number of detections increases. All distance measures must be expressed in same unit of measure. Refinement of MOE depends on unit of measure taken.

4. RATIONALE FOR THE MEASURE: Range of detection gives the capability of a system to detect targets or threat. When moving targets or detectors are involved, range of detection is related to time from detection to contact.

5. DECISIONAL RELEVANCE OF THE MEASURE: Measure may be used in any situation where detection is required for purposes of fire missions, maneuver, or general intelligence. In the referenced study it was a factor in comparing capabilities of alternative intelligence systems.

6. ASSOCIATED MEASURES:

Time to detection
Probability of detection
Proportion of targets detected

7. REFERENCES:

ACN 17874, Mechanized Rifle Company STANO Test.
ACN 17873, Airborne Company STANO Test.
ACN 18026, Armored Cavalry Troop STANO Test.
ACN 17050, Tank Company STANO Test.

SLANT RANGE OF DETECTION

1. DEFINITION OF THE MEASURE: Slant range of detection is the straight line distance between an aircraft and a groundpoint at the moment of detection. It differs from ordinary range of detection which would be the distance from the groundpoint to a spot on the ground beneath the aircraft. Input data are the height of the aircraft above the ground and the angle of line-of-sight from the aircraft to the ground target. Relation of output to input is:

$$\text{slant range of detection} = \frac{\text{height of aircraft (difference between its altitude and groundpoint elevation}}{\text{cosine of the angle of air-to-ground line-of-sight}}$$

2. DIMENSION OF THE MEASURE: Interval measure -- Distance, in terms of a unit of distance such as meters.

3. LIMITS ON THE RANGE OF THE MEASURE: The resolution of the measure is limited by the precision of the input, and can assume any positive value.

4. RATIONALE FOR THE MEASURE: The measure addresses the effectiveness of a detection system in the sense of how far away it can detect. This is related to acquisition performance in two ways: greater slant range of detection means greater probability of detection, and greater range usually means sooner detection.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can discriminate between detection systems in one aspect of effectiveness. It is applicable for both air-to-ground and ground-to-air systems.

6. ASSOCIATED MEASURES:
   - Probability of detection
   - Time to detection
   - Acquisition time

7. REFERENCES:

ACN 16975 , Airborne STANO Systems Test.
ACN 17617, BAHT Field Experiment 43.5, Feb 71.
ACN 18171, Attack Helicopter Daylight Defense Field Experiment 43.6, Jun 72.
ACN 16782, Systems Assessment Model, Oct 71.
ACN M1144, Army Aircraft Survivability Field Experiment 63.3, Jun 66.

FRIENDLY/ENEMY DETECTION RATIO

1. DEFINITION OF THE MEASURE: Friendly to enemy detection ratio is the number of friendly detections of enemy targets (DF) divided by number of enemy detections of friendly locations (DE). Relation of output to input:

$$\text{friendly/enemy detection ratio} = \frac{DF}{DE}$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a pure number expressing the ratio between friendly detections and enemy detections.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The measure is not meaningful until there has been at least one detection by each side, and increases in usefulness as the number of detections increases.

4. RATIONALE FOR THE MEASURE: This measure evaluates the effectiveness of friendly counterintelligence means such as camouflage, concealment, deception and so forth. It is based on the premise that terrain and environmental factors are essentially the same for two forces in the same area, so an unusually low ratio would indicate lack of effectiveness in friendly countermeasures.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate the countermeasure aspect of an intelligence system.

6. ASSOCIATED MEASURES: Percent targets detected
Probability of detection

7. REFERENCES:
ACN 06930, Troop Test Frontier Shield, Feb 67

ACCURACY OF IDENTIFICATION

1. DEFINITION OF THE MEASURE: Accuracy of identification is the proportion of potential targets correctly identified. Correctness of identification may be defined as categorizing targets into friendly or enemy, or may be categorizing by type (aircraft, company CP, artillery position, 817th Armor Battalion, etc.). Whether the identification required is a simple or difficult task, the measure is the proportion of all detected targets correctly classified. Relation of output to input is:

$$\text{accuracy of identification} = \frac{\text{number correctly identified}}{\text{total number detected}}$$

2. DIMENSION OF THE MEASURE: Ratio -- a quotient between all targets considered and those correctly identified. Is a fraction, in terms of a fraction, decimal, or percent of all targets.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is not meaningful until at least one target has been detected, and the usefulness of the measure increases as the denominator increases. The output can assume any value from zero to one, inclusive. The data value cannot be disassociated from the definition of correct identification.

4. RATIONALE FOR THE MEASURE: This measure directly addresses one of the important components of target acquisition. Identification is necessary to complete acquisition.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare means of identification with each other or to a standard. The definition of correct identification is stated in keeping with circumstances. For example, moving target radars may be expected to identify tracked vehicles, but not to identify enemy vs friendly tracked vehicles.

6. ASSOCIATED MEASURES:
   - Time to identify
   - Time to detect
   - Time to estimate range
   - Firing accuracy

7. REFERENCES:

ACN 18171, Attack Helicopter - Daylight Defense Field Experiment 43.6
ACN 14118, SEANITEOPS, Ground Field Experiment 72.8.
ACN 16819, STANO II Part I Test.
ACN 12944, Exploratory Examination in Night Operations, Jun 68.
ACN 17036, MASSTER III Test.

DETAIL OF IDENTIFICATION

1. DEFINITION OF THE MEASURE: Detail of identification is a nominal measure of how many and which details of target identification are accomplished. Details include friend vs foe, type target (in the sense of personnel, truck, tank, or in the sense of armor unit, field CP, logistical installation), direction and rate of movement, size of target, activity (in the sense of moving, digging in, firing), unit designation (in the sense of 817th Armor Battalion), and so forth. The measure is which details are included in the identification.

2. DIMENSION OF THE MEASURE: Nominal -- the output of the measure is a list of details included. It can be used in a interval form by assigning a value to each detail and totaling the value.

3. LIMITS ON THE RANGE OF THE MEASURE: All details of identification have to be defined within their limits. For example, direction of movement can be defined as grossly as forward or withdrawal or as refined as compass azimuth. There is a practical difficulty in eliciting all the details available unless a complete checklist is provided.

4. RATIONALE FOR THE MEASURE: This measure goes directly to one of the most important elements of target identification. Its interval form is an attempt to quantify detail of identification so that a means may be said to identify four out of six details, or if details are ordered in importance, to reach the fourth level of detail of identification.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare different means of identification as to detail. The measure would not ordinarily be used alone; it usually is used in conjunction of accuracy of identification and time to identify.

6. ASSOCIATED MEASURES:

Accuracy of identification
Time to identify

7. REFERENCES:

ACN 17036, MASSTER III Field Test
ACN 07395, Ground Observer Probability of Acquisition Field Experiment 31.1, Sep 68.
ACN 16782, Systems Assessment Model, Oct 71.
ACN 16818, STANO II Test, Dec 69.

TIME TO IDENTIFY

1. DEFINITION OF THE MEASURE: Time to identify is the elapsed time to identification of a target as to friend or foe, or as to type. The input data are time of identification and time of detection. (Alternatively, the start of timing could be time of presentation.) Relation of output to input is:

time to identify = time of identification - time of detection (or presentation)

2. DIMENSION OF THE MEASURE: Interval -- an elapsed time, in units of seconds, minutes, or hours. If the measure is taken over time or under varying circumstances it can be used in the form of mean time to identification or median time to identification.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value can be zero or any positive value. The resolution of the measure is limited by the preciseness of taking start and end time. There is a practical problem in employing the measure when there are instances of failing to identify, or erroneous identification with no provision for correction.

4. RATIONALE FOR THE MEASURE: This measure addresses an important component of target acquisition directly. Problems in identification are assumed to lengthen the time required.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to compare means of identification (techniques, aids, IFF systems, or trained personnel) with each other or with a standard. If accuracy of identification is also measured, this is a supplementary measure.

6. ASSOCIATED MEASURES:
   - Accuracy of identification
   - Exposure time
   - Time to detection
   - Time to estimate range

7. REFERENCES:

ACN 18171, Attack Helicopter - Daylight Defense Field Experiment

IDENTIFICATION TO ENGAGEMENT TIME

1. DEFINITION OF THE MEASURE: Identification to engagement time (or FIRING REACTION TIME) is the elapsed time from the moment of identification of a valid hostile target to the moment of engagement by fire. Input data is in terms of date-time-groups. Relation of output to input is:

identification to engagement time = time of fire minus time of identification

2. DIMENSION OF THE MEASURE: Interval -- Elapsed time in units of of seconds, minutes, hours, or days. If multiple observations are made, the measure can be in the form of a mean or median time.

3. LIMITS ON THE RANGE OF THE MEASURE: Resolution of the measure depends on precision of the timing. Output can assume any positive value. A convention has to be established to handle identifications that do not result in firing. Since time measures are characterized by a skew to the high side, medians are often more useful than means.

4. RATIONALE FOR THE MEASURE: This measure is assumed to be related to reaction time, an important component of total reaction time. It represents the ability of a system to engage a threat once the threat has been identified as a target.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can distinguish between alternative target acquisition systems concerning the timeliness and value of targeting information furnished and the capability of a unit's communications, command and control, and firepower to react to targets.

6. ASSOCIATED MEASURES:
   - Time to detection
   - Target acquisition time
   - Range of detection

7. REFERENCES:
   - ACN 17874, Mechanized Rifle Company STANO Test
   - ACN 18837, OTE FAAR, Phase I

DETECTION TO RECOGNITION TIME

1. DEFINITION OF THE MEASURE: Detection to recognition time is the elapsed time from the moment of detecting a target to the moment of recognition. Recognition is defined as sufficient information to classify a target as either a valid enemy target or not. Unit of measure of input is time in terms of date-time group or as appropriate. Relation of output to input is:

detection to recognition time = time of recognition minus time of detection

2. DIMENSION OF THE MEASURE: Interval -- Elapsed time. Unit of measure of output is linear time in seconds, minutes, hours, and days. The measure can be taken in the form of a mean time or median time when enough individual readings are taken.

3. LIMITS ON THE RANGE OF THE MEASURE: The resolution of the measure depends on the precision of timing used. The output can assume any positive value. Time measures are characterized by a skew to the high side, so that median times are often more useful than mean times.

4. RATIONALE FOR THE MEASURE: It is assumed that the time from detection to recognition is one of the most critical components of acquisition time. Some detection means furnish detection and recognition almost simultaneously while some detectors (such as unattended siesmic sensors, unaided ears, and radars) usually have a long gap between detection and any sort of recognition.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure could be useful in comparing acquisition systems that might be expected to differ in recognition time.

6. ASSOCIATED MEASURES:
- Time to detection
- Acquisition time
- Range of recognition

7. REFERENCES:

ACN 17874, Mechanized Rifle Company STANO Test - Nov 71

PERCENT CORRECT LOCATIONS

1. DEFINITION OF THE MEASURE: Percentage of correct locations is the percentage of reported locations that are close enough to true locations to be counted as correct. The criterion for close enough for correctness has to be stated for application of the measure. The input data are magnitude of the error and criterion for acceptable error. Relation of output to input is:

$$\text{percent correct locations} = \frac{\text{number locations within criterion}}{\text{total number locations}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- Output in terms of percent of locations. Alternatively, the measure could be in the form of a proportion or fraction.

3. LIMITS ON THE RANGE OF THE MEASURE: The denominator has to be at least one, and the usefulness of the measure increases as the denominator increases. Output may assume any positive value from zero to one hundred percent, inclusive. The resolution of the measure is limited by the fineness of the criterion.

4. RATIONALE FOR THE MEASURE: This measure addresses accuracy of locating points, usually applied to locating of targets or other intelligence information. It is a part of the acquisition process. The measure is not as refined as mean offset error or circular error probable, but is ordinarily relatively easy to measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used in any situation where accuracy of locating points is an issue. In the referenced study it was used to determine which night vision devices best provided target locations with criterion limits of ten meters.

6. ASSOCIATED MEASURES:
   - Circular error probable
   - Mean offset error
   - Percent targets detected

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70
ACN 17036, MASSTER III Systems Field Test - Oct 71

LOCATION ERROR TO RANGE RATIO

1. DEFINITION OF THE MEASURE: Location error to range ratio is the quotient of location error divided by range. For example, if the location error in a given location is 10 meters and the range from observer to target is 2,000 meters the ratio would be 20:2,000 or .01 or 1/100. Input data are error distance and range difference, both measured in the same unit of measure. Relation of output to input is:

$$\text{location error to range ratio} = \frac{\text{distance of error}}{\text{range:observer to target}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a quotient, in terms of a ratio (20:2,000), proportion (.01), fraction (1/100), or percentage (1% error).

3. LIMITS ON THE RANGE OF THE MEASURE: Both input distances must be measured in the same unit of measure, such as inches, meters, or kilometers. Resolution of the output depends on refinement of measuring input. Output can be zero or any finite number. If error is always measured as a positive offset error the ratio will be positive, but in circumstances under which positive and negative errors can compensate for each other, the ratio could be positive or negative.

4. RATIONALE FOR THE MEASURE: This is a measure of error in location, as an indicator of accuracy of location, but has the additional information of the range, which allows the significance of the error to be considered.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is useful in any comparison involving accuracy of location. In the referenced study the measure was used to compare night vision divices in accuracy of target acquisition.

6. ASSOCIATED MEASURES:
   - Mean location error
   - Mean offset location error
   - Pct accurate locations

7. REFERENCES:

ACN 12944, Exploratory Examination in Night Operations Field Experiment 71.4 - Jun 68.

ACN 07395, Ground Observer Probability of Acquisition Field Experiment 31.1, Sep 68.

MEAN ERROR

1. DEFINITION OF THE MEASURE: Mean error is the arithmetic mean of all observed distances from reported values to the true value. Also called "average miss distance." That is, it is the mean of all lengths of offset error when all offset errors are treated as positive values regardless of their vector. The input data are the measured distance from each observed location to the true location. Relation of output to input is:

$$\text{mean error} = \frac{\sum^{n} (\text{each error distance from reported location to actual location})}{\text{number of reported locations}}$$

2. DIMENSION OF THE MEASURE: Ratio -- An arithmetic mean expressed in terms of an appropriate measure of length such as inches, meters, or kilometers. Alternatively, the measure could be in the form of a median error, mean square error, standard deviation of error, geometric mean error, or quadratic mean error.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can assume any positive value. This MOE is limited to expressing the amount of error in positive values regardless of the direction of error. The usefulness of the measure improves as the size of the denominator increases.

4. RATIONALE FOR THE MEASURE: This measure addresses the degree of error directly when the direction of the error does not matter. All errors are counted as error; positives and negatives do not offset each other. When all errors are errors regardless of direction, which is usually the case, the mean error is the simplest and most direct measure.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure is useful in any evaluation where accuracy of location is significant, as in the case of firing rounds at a target or in reporting the location of an enemy position.

6. ASSOCIATED MEASURES:

Percent correct locations	Proportion hits
Mean offset error	Circular error probable

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment 72.8 - May 70.

ACN 18288, Artillery Versus Moving Targets Follow-On (REACT), Jul 72.

ACN 17271, Ability to Adjust Artillery on Moving Materiel Targets Field Experiment 32.1.

ACN 16782, Systems Assessment Model, Oct 71.

ACN 13233, Land Navigation Systems Troop Test, Jul 70.

PERCENT TARGETS ACQUIRED

1. DEFINITION OF THE MEASURE: Percent targets acquired is the percentage of targets acquired out of all targets presented. Acquired is defined as detected, recognized, identified, and located. Targets presented is defined as all potential targets in the area of influence. Input data are number of potential targets and number of targets acquired. Relation of output to input is:

$$\text{percent of targets acquired} = \frac{\text{number targets acquired}}{\text{number targets presented}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of acquired targets out of total targets (e.g. 10%). Alternatively, the measure could be in the form of a proportion (.10), fraction (21/210), or ratio (1:10).

3. LIMITS ON THE RANGE OF THE MEASURE: The value of the measure increases as the size of the denominator increases. The output can assume any value from zero to one hundred percent, inclusive.

4. RATIONALE FOR THE MEASURE: This measure addresses effectiveness of target acquisition directly. It subsumes detection, identification, recognition, and location, and is therefore a more general measure for overall comparison of acquisition systems.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is suitable for comparing alternative candidate acquisition systems in amount of acquisition. It would ordinarily be used in conjunction with measures of accuracy and timeliness of acquisition.

6. ASSOCIATED MEASURES:
   - Proportion of targets detected
   - Pct correct identifications
   - Pct correct locations
   - Mean error of acquisition
   - Time to acquisition

7. REFERENCES:
   ACN 17050, Tank Company STANO Test - May 72

MEAN TIME TO ACQUISITION

1. DEFINITION OF THE MEASURE: Mean time to acquisition is the arithmetic average of the elapsed times to complete all successful acquisitions. Acquisition is defined as including detection, recognition, identification, and location of the target. Input data are the elapsed times for each completed acquisition. Relation of output to input is:

$$\text{mean time to acquisition} = \frac{\sum^{n} (\text{elapsed time each successful acquisition})}{\text{number successful acquisitions}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output in terms of an average time in seconds, minutes, hours, or days as appropriate. Could also be used in the form of a "median time to acquisition".

3. LIMITS ON THE RANGE OF THE MEASURE: The number of successful acquisitions must be enough to average out large differences from chance factors in the conditions concerned. The output value can not be dissociated from the circumstances under which it was derived. The output may assume any positive value.

4. RATIONALE FOR THE MEASURE: This measure directly addresses the timeliness of acquisition. It applies only to the case of completed, successful acquisitions and not to the expected time to acquisition of a target. Since it subsumes other time measures (such as time-to-detection) it is a grosser measure suitable to the evaluation of larger systems.

5. DECISIONAL RELEVANCE OF THE MEASURE: This measure may be used in any situation in which timeliness of target acquisition is a factor.

6. ASSOCIATED MEASURES:
   - Time to detection
   - Time to identification
   - Expected time to acquisition

7. REFERENCES:

ACN 14118, SEANITEOPS Ground Field Experiment - May 70

ACN 07395, Ground Observer Probability of Acquisition Field Experiment 31.1, Sep 68.

ACN 18288, Artillery Versus Moving Target Follow-on (REACT) Field Experiment 32.2, Jul 72.

ACN 17271, Ability to Adjust Artillery on Moving Materiel Targets Field Experiment 32.1.

ACN 03067, IRUS Field Experiment 65.1, Aug 67.

ACN 16914, M60A1 Add-on Stabilization Troop Test, Apr 72.

ACN M1144, Army Aircraft Surveillance Field Experiment 63.3, Jun 66.

PERCENT TIME TARGET TRACKED

1. DEFINITION OF THE MEASURE: Percent time target tracked is the total time a target is under observation, as a percentage of the total time the target is in the area of operations. Input data are each of the elapsed times the target is under observation, and the total time the target is in the AO. Relation of output to input is:

$$\text{Percent time target is tracked} = \frac{\sum^{n} (\text{each elapsed time target under observation})}{\text{time target leaves AO minus time enters}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a ratio in terms of percentage of time target exists as a significant target. Several such observations could be combined into a mean percent time, or median.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any value from zero to one hundred percent. The measure is often difficult to take because it sometimes requires collecting a set of short elapsed times. The measure is not as meaningful for stationary targets but is still valid. Destruction of the target must be treated as "leaving the AO".

4. RATIONALE FOR THE MEASURE: The measure directly addresses a relevant military issue in intelligence. It is a true measure of effectiveness rather than a measure of performance because the denominator is the theoretic 100% effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually used to evaluate intelligence systems in effectiveness. In ACN 17036 it was used to compare intelligence collection devices, but it is equally applicable to whole intelligence systems.

6. ASSOCIATED MEASURES: Percent enemy positions known
Time to detection
Probability of detection

7. REFERENCES:
ACN 17036, MASSTER III Test

PERCENT TARGETS ATTACKED

1. DEFINITION OF THE MEASURE: Percent targets attacked is the percentage of all targets presented which are attacked. Input data are number of targets presented and number of targets attacked. These are also broken down into types of targets. Relation of output to input is:

$$\text{pct tgts attacked} = \frac{\sum \text{(number each type tgt attacked)}}{\sum \text{(number each type tgt presented}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- A percentage in terms of percent of targets.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure has a weakness in that any target not attacked for any reason detracts from the numerator. Targets which could be attacked but which are not attacked for tactical reasons depreciates the percentage. The output may vary from zero to one hundred percent.

4. RATIONALE FOR THE MEASURE: This measure goes beyond percent of targets detected totake into account the quality and timeliness of acquisition. Only targeting that goes all the way to an attack is counted.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used as an overall value for comparing alternative target acquisition systems.

6. ASSOCIATED MEASURES:
   - Proportion targets detected
   - Time to acquisition
   - Accuracy of location

7. REFERENCES:

No ACN, "Candidate Measures of Effectiveness for Air Strike Systems", Naval Weapons Center #TP 4687, China Lake, Cal - Sep 69

ACN 10784, Troop Test REDEYE, 1967

COMBAT SERVICE SUPPORT

PERCENT TIME SUPPORT AVAILABLE

1. DEFINITION OF THE MEASURE: Percent time support available is the percentage of the total time observed during which the type of support examined is available on call. In put data are the total elapsed time observed (T) and the sum of the elspsed times of nonavailability. $(\Sigma t_1 \ldots t_n)$ where n is the number of periods of nonavailability. Relation of output to input is:

$$\text{pct time spt available} = \frac{T - (\Sigma t_1 \ldots t_n)}{T} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is a percentage in terms of percentage of total time

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. The resolution of the measure depends on the unit of time interval used, and the usefulness of the measure increases as the value of T increases.

4. RATIONALE FOR THE MEASURE: This measure addresses the amount of support aspect of support effectiveness indirectly. While it ignores uneveness in the amount of support available at different times it is a conventient indicator of overall support available but not actually called for. It is based on the assumption that availability is part of the support mission that should be credited whether or not support is really used.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure would be applicable in situations involving support potential. It can be applied to any kind of support, including close air support, indirect fire support, ~~indirect fire support,~~ resupply support, medical service, personnel and administrative support, maintenance support, chaplain service, or any of a wide variety of support activities that include availability as a part of their mission whether or not actually used.

6. ASSOCIATED MEASURES:
   - Pct (support) req's met
   - Support radius

7. REFERENCES:

No ACN -"Candidate Measures of Effectiveness for Air Strike Systems, Naval Weapons Center #TP 4687, China Lake Cal., Sep 69

RATIO SUPPORT REQUESTS TO COMPLETIONS

1. <u>DEFINITION OF THE MEASURE</u>: The ratio of support requests to completions is the number of support missions completed divided by the number of requests made by supported unit. Input data are the number of requests and number of support deliveries. Relation of output to input is:

$$\text{ratio support requests to completions} = \frac{\text{number of support tasks completed}}{\text{number of support tasks requested}}$$

2. <u>DIMENSION OF THE MEASURE</u>: ratio -- output is a pure number expressing a ratio

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: The ratio may be 1.00 or any positive higher value. The lowest ratio is one because each support task is requested at least once. It can be any higher value if not all support tasks are completed before a repetition or change of the request.

4. <u>RATIONALE FOR THE MEASURE</u>: The measure is based on the thesis that a support mission that is incorrect or too late will result in subsequent requests repeating or changing the support task.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure is intended to evaluate any support system. Support requests may concern supply, transportation, maintenance, medical service, personnel or administrative actions, legal or chaplain service, indirect fire support, engineer, or reconnaissance.

6. <u>ASSOCIATED MEASURES</u>:

   - Percent supply requests met
   - Percent transportation requests met
   - Percent maintenance requests met
   - Proportion supply requirements filled
   - Proportion transport requirements filled
   - Operational availability
   - Percent tasks completed within time

7. <u>REFERENCES</u>:

   None - this is a potential measure

DOCUMENT FORM EFFECTIVENESS

1. DEFINITION OF THE MEASURE: Document form utilization effectiveness is the amount of information conveyed by a form divided by the number of cells on the form. Amount of information is the total number of options excluded. (See MOE entitled "AMOUNT OF INFORMATION"). Number of cells is the number of independent answers, such as blanks, boxes, or checks. Relation of output to input is:

$$\text{Document form effectiveness} = \frac{\text{total number of options excluded}}{\text{number cells}}$$

2. DIMENSION OF THE MEASURE: Ratio -- The output is the average number of options excluded, or average amount of information per cell.

3. LIMITS ON THE RANGE OF THE MEASURE: The output is a positive integer equal to or greater than the number of cells, with no top limit.

4. RATIONALE FOR THE MEASURE: The measure indicates the amount of information conveyed by a form, taking into account the length of the form.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to compare the effectiveness of document forms. A low value indicates that more information should be conveyed, or that the same amount of information should be conveyed in less cells.

6. ASSOCIATED MEASURES: Amount of information. Reporting time.

7. REFERENCES: Article: "Systems Approach to Effective Documentation," Recent Research in Maritime Transportation, National Academy of Sciences National Research Council Publication #592.

AMOUNT OF INFORMATION CONVEYED

1. DEFINITION OF THE MEASURE: Amount of information conveyed is the sum of options excluded by data entries. A yes/no entry has only two options and the answer excludes one, so its value is one. An answer as to which of six subordinate units is answering excludes five options. An answer giving a location to the nearest ten meters in an area that has 1,000 ten-meter blocks excludes 999 options. A date excludes the rest of the days in the total applicable time period. In each answer the options excluded equal the number of possible options (O_i) minus one. The output is the sum of options excluded:

$$\text{information} = (O_i - 1) + (O_2 - 1) + \ldots (O_n - 1)$$

$$= (O_1 + O_2 \ldots + O_n) - n$$

$$= \left[\sum_{i=1}^{n} O_i \right] - n$$

2. DIMENSION OF THE MEASURE: Interval -- the output is a positive integer.

3. LIMITS ON THE RANGE OF THE MEASURE: The output value can assume any positive integer value equal to n or higher. Infinite numbers of options must be excluded by always specifying the highest number of options regardless of how high the value may be.

4. RATIONALE FOR THE MEASURE: The measure is a direct indication of the amount of information conveyed, in terms of the total number of erroneous possibilities excluded.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is applicable to evaluating the amount of information conveyed by a given information system. It is most applicable to forms and standardized messages but can be applied to free form presentations by counting the number of independent points addressed.

6. ASSOCIATED MEASURES:
   - Document form Effectiveness
   - Time to decision
   - Options remaining

7. REFERENCES:
   None, this is a potential measure.

PERCENT SUPPLY REQUESTS MET

1. DEFINITION OF THE MEASURE: Percent supply requests met is the percentage of all supply requests made by a unit that are met by the combat service support system. Input data are the number of valid supply requests made, and the number of these that are met. Relation of output to input is:

$$\text{percent supply requests met} = \frac{\text{number of supply requests met}}{\text{number of supply requests}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is a percentage, in terms of supply requests

3. LIMITS ON THE RANGE OF THE MEASURE: The output can vary from zero to one hundred percent. This measure is limited in that its resolution is at the level of whole requests, and does not address differences in size or importance of requests. This measure is not as refined as proportion of supply requirements met but is a simpler, less expensive measure to take.

4. RATIONALE FOR THE MEASURE: The measure is an indicator of how effective the combat service support system is in meeting supply needs.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate the supply aspect of a combat service support system.

6. ASSOCIATED MEASURES:
   - Time to resupply
   - Proportion of supply requirements filled

7. REFERENCES:
   - ACN 06930 - Troop Test Frontier Shield, Feb 67

PERCENT SUPPLY REQUIREMENTS FULFILLED

1. <u>DEFINITION OF THE MEASURE</u>: Percent supply requirements fulfilled is the percentage of supply requirements met. (It is not the percent of supply requests met.) Input data are the amount of supplies requested, usually counted in terms of "days of supply" (DOS) and the amount supplied. Relation of output to input is:

$$\text{pct supply req's fulfilled} = \frac{\text{amount of supplies met (in DOS)}}{\text{amount of supplies requested (in DOS)}} \times 100$$

2. <u>DIMENSION OF THE MEASURE</u>: Ratio -- A percentage in terms of percentage of supplies required.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: A percentage can vary from zero to one hundred per cent. To apply the measure each class of supplies has to be expressed in DOS or some other common denominator which requires agreeable definitions of the unit of measure. The measure ignores differences in importance of different classes of supply.

4. <u>RATIONALE FOR THE MEASURE</u>: The measure directly addresses amount of supplies provided. It is a more refined measure than percent of supply requests filled because it takes into account differing sizes of requests.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure can be used to evaluate supply systems.

6. <u>ASSOCIATED MEASURES</u>:
   - Pct of supply requests met
   - Pct of supplies delivered by time required

7. <u>REFERENCES</u>:

ACN 17494, Development of a Divisional War Game Model (DIVWAG) - Dec 71

TIME TO RESUPPLY

1. DEFINITION OF THE MEASURE: Time to resupply is the elapsed time required to rearm, refuel, or otherwise resupply an aircraft, vehicle, or unit. Input is start time and completion time. The measure is the difference in hours, minutes, or days as appropriate. Relation of output to input is:

$$\text{time to resupply} = \text{completion time} - \text{start time}$$

2. DIMENSION OF THE MEASURE: Interval measure -- output is in terms of hours, minutes, or days. Sometimes used in the form of a ratio measure such as "average time to resupply" or "mean time to resupply per vehicle."

3. LIMITS ON THE RANGE OF THE MEASURE: Measure may assume any positive value above zero. Measure is applicable only to the conditions under which it is taken, and for the aircraft, vehicle, column, flight, or unit for which it is taken.

4. RATIONALE FOR THE MEASURE: This measure is the most direct measure of the timeliness of a refueling, rearming, or other resupply operation. Measure can include waiting time and service time or be limited to service time. It can easily be converted to a ratio measure when more appropriate.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually most useful in measuring aspects of a combat service support system. In the referenced study aircraft refueling and rearming (combined) was under study. It might also be used as a supplementary measure in comparing materiel systems.

6. ASSOCIATED MEASURES:
   - Resupply rate
   - Resupply frequency
   - Operational readiness
   - Missions per day
   - Proportion of resupply requests met

7. REFERENCES:

ACN 17073, Aircraft Refueling and Rearming in Forward Areas (FAAR Study).

ACN 00004, A Method for Integration of Medical Accounting, Reporting, Supply and Regulating of the Army in the Field into ADSAF-CS_3 Program.

ACN 11585, Division Logistics System Test

ACN 06930, Troop Test Frontier Shield, May 66

TIME TO REQUIRED RESUPPLY

1. DEFINITION OF THE MEASURE: Time to required resupply is the length of time a basic load of ammunition is expected to last in engagement. Input measures are size of basic load (in rounds, tons, or DOA), amount of ammunition expended, and elapsed time under engagement. Relation of output to input is:

$$\text{time to required resupply} = \frac{\text{amount of basic load}}{\text{amount ammo expended/elapsed time}}$$

2. DIMENSION OF THE MEASURE: Rational number -- unit of measure of output is time. The two input measures in terms of amount of ammo cancel each other out, leaving the output in time. It is rational in the sense that it is time per basic load.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure is meaningless until the first ammunition expenditure has recurred. The measure becomes more useful as time under engagement increases. The output can assume any positive value. If different types of ammunition are used, the amount must be measured in weight or DOA. The unit of measure for amount must be the same in numerator and denominator.

4. RATIONALE FOR THE MEASURE: This measure addresses the burden to the resupply system. It may be thought of as required resupply frequency or expected life of basic load. If resupply capability is fixed, it is a measure of sustainability.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure may be used to evaluate competing firepower systems in terms of sustainability or to evaluate doctrinal concepts of combat service support.

6. ASSOCIATED MEASURES:
   Ammunition expenditure rate
   Percent of basic load expended

7. REFERENCES:
   None; this is a proposed potential measure.

MEAN TIME INTERNAL DISTRIBUTION

1. DEFINITION OF THE MEASURE: Mean time internal distribution is the average time required to distribute ammunition (or other supplies) to users within an organization. Input data are the times of delivery to the organization and completion of distribution, and the number of distributions observed. Relation of output to input is:

$$\text{mean time internal distribution} = \frac{\sum^{n} \text{(each elapsed distribution time)}}{\text{number distributions}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is an arithmetic mean, in terms of mean number of minutes or hours

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. There is a danger in using mean times, because one or two unusually long times may disproportionately influence the average. A median time may be more useful.

4. RATIONALE FOR THE MEASURE: The measure addresses timeliness of the internal combat service support of an organization, as opposed to the service elements supporting a unit. This last step in the combat service support chain may be critical in tactical circumstances.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to assess a units internal supply distribution system.

6. ASSOCIATED MEASURES:

Time to resupply
Percent supply requests met
Percent supply requirements filled

7. REFERENCES:

No ACN, Reserve Components Revised ATT, USCONARC, Mar 72

PROPORTION AMMUNITION REMAINING

1. DEFINITION OF THE MEASURE: Proportion ammunition remaining is the quotient of amount of ammunition remaining divided by initial amount of ammunition prior to a specified firing engagement. Input may be in terms of rounds, tons, or stated "days of ammunition." Relation of output to input is:

$$\text{proportion of ammunition remaining} = \frac{\text{amount ammunition remaining}}{\text{initial amount ammunition}}$$

2. DIMENSION OF THE MEASURE: ratio -- A proportion in the form of a decimal or percentage fraction of a stated amount of ammunition.

3. LIMITS ON THE RANGE OF THE MEASURE: The proportion may assume any value from zero to unity. The output is a function of the firing task and can not be dissociated from the conditions under which it was derived. If various types of ammunition are involved, they have to be handled in a common measure.

4. RATIONALE FOR THE MEASURE: This measure addresses the effectiveness of firepower and logistics directly in the sense that accomplishing a mission with less than the maximum ammunition indicates more efficient firing.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare competing firepower systems, alternative ammunition supply systems, or even whole systems to the extent that this can be considered a sensitive enough measure of target acquisition, mobility, and command and control efficiency.

6. ASSOCIATED MEASURES:

Proportion rounds expended	Percent resupply req's met
Ammo expenditure rate	Probability of success
Resupply rate	Casualties inflicted

7. REFERENCES:

ACN M3523 - Small Arms Weapons Systems (SAWS) Field Experiment 65.4, May 66

PERCENT TRANSPORT REQUESTS MET

1. DEFINITION OF THE MEASURE: Percent transport requests met is the percentage of all requests for vehicular or air transport made by a unit that are met by the combat service support system. Input data are the number of valid requests made and the number for which transportation is provided. Relation of output to input is:

$$\text{percent transport requests met} = \frac{\text{number of transport requests met}}{\text{number of transport requests}} \times 100$$

2. DIMENSION OF THE MEASURE: ratio -- output is a percentage in terms of percentage of requests

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent. This measure is not very refined because it treats all requests equally, ignoring differences in size and importance and transportation needs in different requests. While it is not as refined as proportion of transportation requirements filled, it is simpler and less expensive to measure.

4. RATIONALE FOR THE MEASURE: The measure is an indicator of how effective the combat service support system is in meeting transportation needs.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to evaluate the transportation aspect of a combat service support system.

6. ASSOCIATED MEASURES:
   - Proportion transportation requirements filled
   - Percent moves within time ordered

7. REFERENCES:
   - ACN 06930 - Troop Test Frontier Shield, Feb 67

PROPORTION TRANSPORTATION REQUIREMENTS FILLED

1. DEFINITION OF THE MEASURE: Proportion transportation requirements filled is the amount of transportation provided divided by the amount of transportation required. Amount of transportation is in terms of number of personnel-miles, ton-miles, or other suitable expression of amount of cargo and distance. Relation of output to input is:

$$\text{proportion transportation requirements filled} = \frac{\text{amount of transportation provided (payload x dist)}}{\text{amount of transportation required (payload x dist)}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is a pure number expressing a proportion of requirements

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to unity. If different types of payloads are involved, they must be converted to a common denominator. Different payloads and different distances must be summed.

4. RATIONALE FOR THE MEASURE: The measure directly addresses the effectiveness of the transportation aspect of the combat service system.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate service support systems.

6. ASSOCIATED MEASURES:
   - Percent transportation requests met
   - Percent moves within time ordered

7. REFERENCES:
   - ACN 11585, Division Logistics System Test

PERCENT RUNS WITH PAYLOAD BOTH WAYS

1. DEFINTIION OF THE MEASURE: Percent runs with payloads both ways is the percentage of all transport runs dispatched that carry a payload in both directions, going out and return. Input data are the number of transport runs dispatched and the number of them that have payloads both ways. Relation of output to input is:

$$\text{percent runs with payload both ways} = \frac{\text{number of runs with payload both ways}}{\text{number runs dispatched}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a percentage of all transport runs. Several observations could be combined into an average, or a more refined measure could be computed by figuring into the computation the proportion of maximum possible payload capacity actually carried each way.

3. LIMITS ON THE RANGE OF THE MEASURE: The measure could theoretically vary from zero to one hundred percent, but since no run would be expected to be dispatched without a payload in at least one direction, the output would ordinarily be expected to fall between 50% and 100%. A convention must be established for vehicles or aircraft lost to tactical action.

4. RATIONALE FOR THE MEASURE: This measure addresses effectiveness of a transportation system. Since a system that carries a payload in both directions 100% of the time is clearly at maximum dispatch effectiveness, the measure is a true measure of effectiveness.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is intended to evaluate effectiveness of truck or aircraft transport systems. It does not stand alone because this measure could approach 100% by delaying until a return payload is assured. It can be used in conjunction with a time measure.

6. ASSOCIATED MEASURES:

Time to mission completion	Proportion of supply requirements met
Reduction in cube requiring transport	Percent transport requests filled
Percent cargo unitization	Resupply rate
Supply throughout effectiveness	Cargo handling rate
Percent missions within time	Time to required resupply

7. REFERENCES:

ACN 06930 - Troop Test Frontier Shield, Feb 67

EVACUATION RATE

1. DEFINITION OF THE MEASURE: Evacuation rate is the number of units evacuated during a specified time period. Input data are the number of items (casualties, disabled vehicles, weapons requiring repair, downed but recoverable aircraft, or refugees) evacuation and the total time required for evacuation. Relation of output to input is:

$$\text{evacuation rate} = \frac{\text{total number of (items) evacuation}}{\text{completion time of evacuation minus start time}}$$

2. DIMENSION OF THE MEASURE: ratio -- output is a ratio, such as 5 casualties per hour, four disabled tanks per day, 731.14 damaged rifles per week, or 2,000 refugees per month

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be any positive number. The measure is meaningless until there has been at least one evacuation, and increases in usefulness as either the numerator or denominator increases. Since a rate may change, the value can not be dissociated from the time period during which it was derived.

4. RATIONALE FOR THE MEASURE: The measure addresses the capacity of an evacuation system, such as a medical evacuation unit or a vehicle maintenance towing element. Both amount and timeliness are taken into account.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate any evacuation system.

6. ASSOCIATED MEASURES:
   Mean evacuation time

7. REFERENCES:
   ACN 00004, A Method for Integration of Medical Accounting, Reporting, Supply and Regulating of the Army in the Field into ADSAF - CS_3 Program
   ACN 10225 - ROAD Organization: Litter Bearer Requirements, Oct 66

MEAN TIME TO RESTORE

1. DEFINITION OF THE MEASURE: Mean time to restore (MTTR), sometimes called "mean time to repair" is the average elapsed time to restore to service a failed materiel item. Input data are the elapsed times and the number of failures restored. Relation of output to input is:

$$MTTR = \frac{\sum^{n} \text{(each elapsed time to restore)}}{\text{number restorations}}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is a mean in terms of average time in minutes, hours, days, or as appropriate.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may assume any positive value. The measure is meaningless until there has been at least one restoration, and increases in usefulness as the number of restorations increases. A restoration has to be defined. In some cases it refers only to the time required to repair the failed item, in which case a convention has to be established for irreparable items. In most cases a restoration is counted if an item is replaced from the maintenance float so that if the failed item is repaired and put into the maintenance float before the float reaches zero, the elapsed time is only the time required to replace a failed item with one from a float. Also in some cases a re-supply replacement is counted as restoration so that time to restore is to repair or replacement, whichever comes first.

4. RATIONALE FOR THE MEASURE: This measure addresses the timeliness aspect of a maintenance system directly.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is usually used to evaluate maintenance systems but can also be used to compute maintenance requirements.

6. ASSOCIATED MEASURES:

- Failure rate
- Mean time to failure
- Proportion maintenance float available
- Percent maintenance requests met

7. REFERENCES:

ACN 10698, Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field, Jun 67
ACN 11585, Division Logistics Systems Test, Jul 69
ACN 04722, Maintenance of ADPE in the Army in the Field (75)
ACN 06500, Maintenance Study - 75
ACN 13921, Examination of the Logistical Support Operations for an Independent Brigade
ACN 13964, Integration of DS Aviation Maintenance Units
ACN 16494, Family of Army Vehicles Study
ACN 06930, Troop Test Frontier Shield
No ACN - System Effectiveness Status Report (PERSHING)
No ACN - "Candidate MOE for Air Strike Systems," Naval Weapons Center Document #TP 4687
ACN 16818, STANO II Test
ACN 06990, Division DS Maintenance Company TOE 29-138F Test

MEAN MEDEVAC TIME

1. <u>DEFINITION OF THE MEASURE</u>: Mean medevac time is the average elapsed time required to evacuate a casualty from the site of injury to the point of first medical treatment. Input data are time each casualty reaches treatment (t_t), time each casualty is inflicted (t_c), and the number of casualties (n). Relation of output to input is:

$$\text{mean medevac time} = \frac{\sum^{n} (t_t - t_c)}{n}$$

2. <u>DIMENSION OF THE MEASURE</u>: Ratio -- An average in terms of average time.

3. <u>LIMITS ON THE RANGE OF THE MEASURE</u>: The output can assume any positive value. Observed values have ranged from a mean medevac time of 14 minutes in Vietnam operations (1965-67) to over two hours in the WW II Italian campaign (1944). The resolution of the measure depends on the precision of time measurement and the application usefulness increases as the denominator increases.

4. <u>RATIONALE FOR THE MEASURE</u>: The measure addresses timeliness of the medical evacuation system directly.

5. <u>DECISIONAL RELEVANCE OF THE MEASURE</u>: The measure is used to evaluate medical evacuation systems.

6. <u>ASSOCIATED MEASURES</u>: Evacuation rate.

7. <u>REFERENCES</u>:

ACN 06930, Troop Test Frontier Shield, 1967.

ACN 10225, ROAD Organization: Litter Bearer Requirements, 1967.

ACN 11585, Division Logistics Systems Test, 1969.

ACN 00004, A method of Integration of Medical Accounting, Reporting, supply, and regulating of the Army in the Field into ADSAF-CS_3 Program.

PERCENT CASUALTIES SURVIVING

1. DEFINITION OF THE MEASURE: Percent surviving is the percentage of all casualties taken that survive to the end of a specified observation period. Input data are the number of casualties and the number of casualties expiring. Relation of output to input is:

$$\text{percent casualties surviving} = \frac{\text{number of casualties minus number expiring}}{\text{number of casualties}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a quotient in terms of percentage of casualties

3. LIMITS ON THE RANGE OF THE MEASURE: The output may vary from zero to one hundred percent, but is constrained by the number of casualties who receive irreparably mortal wounds. Since the cumulative percent surviving is always ultimately zero, the time period observed must be stated.

4. RATIONALE FOR THE MEASURE: The measure indirectly addresses quality of a medical system. It has obvious military significance in terms of conservation of forces.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare alternative medical systems under the same circumstances.

6. ASSOCIATED MEASURES:
   - Percent casualties returned to duty
   - Mean medevac time

7. REFERENCES:
   - ACN 06930 - Troop Test Frontier Shield, 1967

PERCENT CASUALTIES RETURNED TO DUTY

1. DEFINITION OF THE MEASURE: Percent casualties returned to duty is the percentage of all personnel becoming casualties who are returned to duty within the time observed. Input data are the number of casualties and the number of casualties returned to duty. Relation of output to input is:

$$\text{percent returned} = \frac{\text{number of casualties returned to duty}}{\text{number of casualties}} \times 100$$

2. DIMENSION OF THE MEASURE: Ratio -- output is a quotient in the form of percentage of casualties

3. LIMITS ON THE RANGE OF THE MEASURE: The output could vary from zero to one hundred percent, but the top limit is constrained by the casualties that can never be returned to duty. Furthermore the cumulative percentage returned is sensitive to time so that the measure can not be dissociated from the time period involved.

4. RATIONALE FOR THE MEASURE: The measure indirectly addresses the quality of a medical system. While it is apparent that some casualties cannot be returned to duty in any length of time, a higher percentage for any given time period is assumed to indicate a more effective medical system.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure can be used to compare medical systems under identical circumstances for purposes of trying a hypothesized organization, procedure, or equipment issue.

6. ASSOCIATED MEASURES:
   - Mean treatment time
   - Percent casualties surviving

7. REFERENCES:

ACN 00004, A Method for Integration of Medical Accounting, Reporting, Supply, and Regulating of the Army in the Field into ADSAF - CS_3 Program

MEAN TIME TO RETURN TO DUTY

1. DEFINITION OF THE MEASURE: Mean time to return to duty (or, mean treatment time) is the arithmetic average of all times spent by casualties in the medical system, excluding those not returned to duty. Input data are the date of onset of wound, injury, or illness (ci) and the date returned to duty (ri) of each casualty, and the number of casualties (n). Relation of output to input is:

$$\text{mean treatment time} = \frac{\sum_{i=1}^{n} (r_i - c_i)}{n}$$

2. DIMENSION OF THE MEASURE: Ratio -- Output is an average in terms of average number of days.

3. LIMITS ON THE RANGE OF THE MEASURE: The output can be any positive integer. The measure has two serious weaknesses. One, it does not take into account those casualties never returned to duty, and two, it is difficult to interpret whether a low value is desirable or not.

4. RATIONALE FOR THE MEASURE: The measure is based on the theorem that the sooner a medical system returns casualties to duty the better the system is supporting a force. It has to be noted, however, that it might also mean inadequate treatment is being given.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is an indirect indicator of the effectiveness of a medical system. Due to its weaknesses it cannot be used alone, but would have to be used in conjunction with other indicators such as percent patients surviving.

6. ASSOCIATED MEASURES:
   - Percent casualties surviving
   - Percent casualties returned to duty
   - Mean patient backlog

7. REFERENCES:
   None - this is a potential measure

PATIENT BACKLOG

1. DEFINITION OF THE MEASURE: Patient backlog is the number of patients at a medical facility in excess of treatment capacity. The input data are the number of patients admitted and the capacity. Relation of output to input is the subtracted difference:

patient backlog = (nr patients admitted) - (nr patients capacity)

2. DIMENSION OF THE MEASURE: interval -- output is a number count in terms of number of patients. Alternatively, data could be taken over time to compute a ratio measure such as mean patient backlog, expected patient backlog or peak patient backlog.

3. LIMITS ON THE RANGE OF THE MEASURE: The output may be zero or any positive or negative integer. In ratio form it may be fractional.

4. RATIONALE FOR THE MEASURE: The measure addresses effectiveness of a medical treatment center in terms of treatment in relation to requirement.

5. DECISIONAL RELEVANCE OF THE MEASURE: The measure is used to evaluate a medical treatment system.

6. ASSOCIATED MEASURES:
   Casualties restored to action
   Casualty treatment rate

7. REFERENCES:
   AGN 00004, A Method for Intergration of Medical Accounting, Reporting, Supply and Regulating of the Army in the Field into ADSAF - CS_3 Program.

ANNEX A

BIBLIOGRAPHY

US ARMY REGULATIONS

AR 5-5. THE ARMY STUDY SYSTEM. 15 February 1971.

AR 70-10. TEST AND EVALUATION DURING DEVELOPMENT AND ACQUISITION OF MATERIEL. 21 July 1971.

AR 71-1. ARMY COMBAT DEVELOPMENTS. Change 1, 16 September 1968.

AR 71-3. USER FIELD TESTS, EXPERIMENTS AND EVALUATION. 19 March 1968.

BOOKS

A MATHEMATICAL THEORY OF SYSTEMS ENGINEERING--THE ELEMENTS, A. Wayne Wymore, Wiley and Sons, Inc., New York, New York, 1967.

DIMENSIONAL ANALYSIS, Revised Edition, P. W. Bridgman, Yale University Press, New Haven, Connecticut, 1948.

FOUNDATIONS OF MEASUREMENT, Volume 1, D. H. Krantz, R. D. Luce, P. Suppes, A. Tversky, Academic Press, New York, New York, 1971.

INTRODUCTION TO OPERATIONS RESEARCH, C. West Churchman, et al, Wiley and Sons, Inc., New York, New York, 1957.

INTRODUCTION TO SCIENTIFIC MEASUREMENT, Robert Hooke, Holden-Day, Incorporated, San Francisco, 1963.

MODERN ELEMENTARY STATISTICS, 2nd Edition, John E. Freund, Prentice-Hall, Incorporated, Englewood Cliffs, New Jersey, 1960.

NONPARAMETRIC STATISTICS FOR THE BEHAVIORAL SCIENCES, Sidney Siegel, McGraw-Hill Book Company, Inc., New York, New York, 1956.

OPERATIONS RESEARCH--METHODS AND PROBLEMS, Maurice Sasieni, Arthur Yaspan, Lawrence Friedman, Wiley and Sons, Inc., New York, New York, 1959.

STATISTICAL THEORY AND METHODOLOGY IN SCIENCE AND ENGINEERING, 2d Edition, K. A. Brownlee, Wiley and Sons, Inc., New York, New York, 1965.

THE FOURTEEN SYSTEMS OF UNITS, 2nd Edition, W. R. Varner, O. S. C. Cooperative Association, Corvallis, Oregon, 1948.

THEORY OF GAMES AND ECONOMIC BEHAVIOR, John Von Neumann and Oskar Morgenstern, Princeton University Press, Princeton, New Jersey, 1953.

THEORY OF MEASUREMENT, J. Pfanzagl, Wiley and Sons, Inc., New York, New York, 1968.

JOURNAL ARTICLES

"MEASUREMENT STRUCTURES AND PSYCHOLOGICAL LAWS," David H. Krantz, SCIENCE, Vol 175, No. 4029, 31 March 1972.

"ON THE OPERATION KNOWN AS JUDGEMENT," AMERICAN SCIENTIST, Vol 54, No. 4, 1966.

"PRINCIPLES, PROBLEMS, MODELS AND ENGINEERING," H. E. Hoelscher, RESEARCH/DEVELOPMENT Magazine, December 1966.

"THE MEASUREMENT OF COMBAT EFFECTIVENESS," Philip Hayward, OPERATIONS RESEARCH JOURNAL, Vol 16, No. 2, March-April 1968.

PAMPHLETS

A PRIMER OF COST EFFECTIVENESS, William H. Sutherland, Research Analysis Corporation, McLean, Virginia, RAC-TP-250, April 1967.

GUIDE FOR REVIEWERS OF STUDIES CONTAINING COST-EFFECTIVENESS ANALYSIS, I. Heymont, et al, Research Analysis Corporation, McLean, Virginia, IR-240, July 1965.

MATHEMATICS OF MILITARY ACTION, OPERATION AND SYSTEMS, Department of the Army Pamphlet No. 70-5, January 1968.

METHODOLOGY NOTEBOOK FOR ACTION OFFICERS, 2nd Edition, United States Army Combat Developments Command, May 1967.

METHODOLOGY NOTEBOOK FOR ACTION OFFICERS, PART II, Revised Edition, United States Army Combat Developments Command, Combat Support Group, March 1970.

OPERATIONS RESEARCH/SYSTEMS ANALYSIS GLOSSARY, Operations Research/Systems Analysis Executive Course, US Army Management School, Fort Belvoir, Virginia, AM-605-N.1, May 1968.

SYSTEMS ANALYSIS AND COST EFFECTIVENESS, Headquarters, Department of the Army, Office of The Adjutant General, Letter 23 April 1964, Major General J. C. Lambert, AD 450411.

TROOP TEST METHODOLOGY GUIDE. Fred K. McCoy et. al., Technical Operations Inc., CORG-M-305, October 1967

PROCEEDINGS ARTICLES

PROCEEDINGS OF THE UNITED STATES ARMY OPERATIONS RESEARCH SYMPOSIUM, 21-23 May 1969, Durham, North Carolina.

---"On The Use of Models in Interpretation of Data and the Use of Data in Interpretation of Models" by John P. Mayberry.

---"The Relative Kill Productivity Exchange Ratio Technique" by John Spudich.

PROCEEDINGS OF THE UNITED STATES ARMY OPERATIONS RESEARCH SYMPOSIUM, 26-28 May 1971, Durham, North Carolina.

---"Performance Analysis of Proposed Materiel Options" by Channing L. Pao.

---"Measures of Effectiveness for Army Communication Systems" by Daniel S. Lynch.

---"Measures of Effectiveness for Indirect Fire with Non-nuclear Artillery Weapons" by John A. Blomquist.

---"Measures of Effectiveness for Surface to Air Weapons" by Harry X. Peaker.

---"The Concept of Opportunity" by Robert W. Blum.

---"Human Engineering Measures of Effectiveness of System Performance" by Andrew J. Eckles, III.

STUDIES ANALYZED FOR MOE

US ARMY COMBAT DEVELOPMENTS STUDIES

ACN	TITLE
3067.1	CDCEC Experiment 65.1, Infantry Rifle Unit Study 1970-75 (IRUS), Phase I, 15 Aug 1967.
3067.2	CDCEC Experiment 65.1, Infantry Rifle Unit Study 1970-75 (IRUS), Phase IIB and IIBX, July 1965.
1144V	CDCEC Experiment 63.7, Lethality Probabilities of Forward Area Radar Controlled Air Defense Weapons Against Army Aircraft, 1 Jun 1967.
M-1144	CDCEC Experiment 63.3a, Army Aircraft Survivability, UH-7B/M22 Weapon System Evaluation, June 1966.
1144	CDCEC Experiment 63.6, Army Aircraft Survivability-Visually Sighted Weapons.
1514	The Operational Effectiveness of Vapor/Aerosol Weapons Systems (USACDC-CBR)
2627	CDCEC Experiment 60.3, Operations in a Toxic Environment, Interim Report, April 1968.
M3523	CDCEC Field Experiment 65.4, Small Arms Weapons Systems (SAWS), Parts I and II, May 1966.
3598	CDCEC Experiment 65.5, Repetitive Area Search-Moving Target Indication (RAS-MTI), Radar Concept Field Evaluation, Project Michigan, August 1965.
7395	CDCEC Experiment 31.1, Ground Observer Probabilities of Acquisition/Adjustment, September 1968.
7395	CDCEC Experiment 31.1, Target Acquisition Performance by Ground Observers - A Physical Interpretation, July 1968.
7769	CDEC Experiment 71.1, Evaluation of Night Vision Equipment I (ENVE I), September 1966.
7769	CDEC Experiment 72.9, Evaluation of Night Vision Equipment II (ENVE II), September 1968.

ACN	TITLE
7769	CDEC Experiment 72.10, Evaluation of Night Vision Equipment III (ENVE III), December 1968.
00002	Medical Workloads Resultant from Combined Effects of Chemical, Biological, Nuclear, Improved Conventional and Sophisticated Weapons.
00004	A Method for Integration of Medical Accounting Reporting Supply & Regulating of the Army in the Field into ADSAF-CS_3 Program.
00007	Patient Evacuation Systems Phase I Effects of Varying Evacuation Policies Upon the US Army (4 uncl vol and 1 (S) vol)
00008	Inspection of Operational Rations
00009	A Method of Evaluating the Relative Effectiveness of Field Army Medical Systems - Phase IV USACDCMSA 64-2.
00011	Army Aeromedical Evacuation.
00014	Universal Hospital Organizational Base
00079	Field Evaluation, Combat Support Hospital, TOE 8-123, USACDC Medical Service Agency.
00136	Calibration Service in the Army in the Field 1965-1970 Revised.
00137	APP ADPS Gen Eqt Mte CCIS-70.
00240	POL Operations in the Field Army, 1965-1970 /U/.
00244	Supply Functionalization in the Army in the Field.
00264	Computer Assisted Simulation of Supply & Related Systems.
00284	Ground Effect Machines/GEM/Operational Requirements.
00856	A Method of Evaluating the Relative Effectiveness of Field Army Medical Support Systems Phase V.
00874	Postal Management of Official Mail for the Army 1965-70.

ACN	TITLE
00876	Personnel Management Support of the Army in the Field, 1965-70 Administration of Officer & Enlisted Efficiency Reporting Combat Conditions.
00878	Postal Services for the Soldier, 1965-70.
00890	Extension of Personnel Management ADPS to Theater Level.
0899	The Impact of the Radioactive Environment Upon Traditional Chaplain Ministry.
00901	The Impact of Indigenous Religion Upon US Military Operations Under All Conditions of War.
00904	Composition, Jurisdiction, Procedures and Policies of Civil Affairs Tribunals.
00974	Troop Test, Light Armor Battalion.
00983	Troop Test (TT), Armor Units Limited Visibility Operations, 1966.
01647	Organizations and Operational Concepts for Meteorological Service in Support of Army Tactical Operations. (Met Services) 1965-70, CE Agency, 1969.
01681	The LANCE Operational/Cost Effectiveness Study (CDCFAA).
01696	Doctrinal Position of the Chaplain in Civil Affairs Units in the 1970-75 Time Frame.
02330	Subsistence and Food Service for the Army in the Field.
02739	Intermediate Staging Areas for Airborne Operations 75.
02747	Theater Army Communications Systems Requirements, 1965-70 (TACS-70), Vol I-III.
02869	Development of a Military Pay System for Army in the Field 1970.
02874	Troop Test: Overall Effectiveness of Artillery Organizations, Doctrine and Concepts, Aug 65.
02881	Financial Accounting for the Army in the Field.
02894	Graves Registration DPS Requirement Army in the Field 1970.
02908	Field Army Requirements for Tactical Communications (TACOM), Oct 66.

ACN	TITLE
02928	Legal Implications of Projected Automation of Personnel and Administration and Logistics Operation in Support of the Army in the Field.
02950	Economic and Public Finance Functions of the Finance Corps /U/
02955	Troop Test, Road Brigade in Counterguerrilla Activities 1965.
03010	Infantry Rifle Unit Study - 1975.
03025	Army Aircraft Ground Support Equipment.
03062	Shelter Requirements for the Army in the Field.
03123	The Supply and Maintenance Command, TASCOM/Input CSSG 63 - 6 TASTA.
03124	USACDCJAA 65-3, Requirements for Judge Advocate Personnel and Legal Service Support in the Conceptual Framework, The Administrative Support, Theater Army 170/TASTA-70.
03131	AG Functional Support to ASCOM and FASCOM.
03132	Personnel Command & AG Operations 1970.
03133	Medical Command, TASCOM Medical Brigade, FASCOM.
03134	TASTA 70 Chaplain Support
03145	Headquarters Units, TASTA-70.
03147	Troop Test Evaluation of Road Organizations, 1967.
03262	Ammunition Service, FASCOM.
03299	Requirements for Types of Judge Advocate General Service Organization.
03317	Comptroller Service TASTA-70.
03329	Application of Automatic Data Processing Techniques to Movements Management.
03351	Supply and Field Service Support, FASCOM.

ACN	TITLE
03353	POL Service FASCOM/QMA 65-9/Input to TASTA 70.
03368	Maintenance Support FASCOM TASTA 70.
03434	LANCE Cost-Effectiveness Study.
03451	Troop Test, Engineer Combat Battalion, Airborne TOE 5-195T, 1969.
03498	Small Arms Weapons System Study.
04286	Denial of Nuclear Weapons-Army 75, Jul 67.
04584	War Game TASTA 70 Mid Intensity.
04722	Maintenance of ADPE Within Elements of the Army in the Field - 75.
04907	Doctrine for Chaplain Opns in Combined Unified Joint Task Forces and Subordinate Component Commands.
05403	Rifle Evaluation Study (CDCIA).
05443	Dynamics of Firepower and Maneuver Phase II (CDCIAS).
05546	Troop Test, Army Air Mobility Evaluation (ARAME), 1965.
06073V	Troop Test, Waterbucket II, 1966.
06081	Troop Test, Troop Acceptability Test, Army Small Arms Weapon Systems.
06396	Field Artillery Cannon Nonnuclear Ammunition Study.
06488	Artillery (1970-1975).
06492	Communications-Electronics-75, Sep 68 & Mar 69.
06497	Transportation 75.
06498	Medical Service 75 (Executive Summary).
06500	Maintenance 75.
06501	Supply 75.

ACN	TITLE
06502	Personnel & Administration 75/70-75.
06503	Chaplain Support 75.
06505	Judge Advocate General 75.
06534	The Transportation Service TASTA-70/Revision.
06557	Medical Implications of Chemical and Biological Operations/U/ Substudy 5, Mandrake Root.
06819	Sensitivity Analysis of Theater Evaluation Policy/ Cargo Project 67-23.
06841	Army Logistic Support Concept - Air Lines of Communication (LOG-ALOC II).
06930	Troop Test, Frontier Shield, 1967.
07297	Integration of the Centralized Army Military Pay System into CS_3 ADSAF.
07298	Application of Automatic Data Processing Techniques to Ammunition and Missile Maint for the Army in the Field.
07344	CASSARS ALOC.
07346	Optimum Mix of Artillery Units (1971-1975).
07356	Tank, Antitank, Assault Weapon Systems Requirement Study, Phase III.
10225	Litter Bearer Requirements Road Organization.
10589	Area Optometric Support of Nondivisional Units.
10698	Automatic Data Processing Techniques to Support Army Aircraft Maintenance for the Army in the Field.
10784	Troop Test REDEYE/Interim, 1967.
11161	Troop Test, Underwater Reconnaissance.
11360	Hostile Observation Satellite Study (HOSS), CORG-M-381, Jul 70.
11585	Organization and Operation of the Division G4 Section Standardized Division G4/DISCOM Commander Relationship Worldwide.

ACN	TITLE
11670	CDCEC Experiment 72.2, Reduction of Noise Level of Operational Aircraft Experiment (RENO), 11 Dec 1967.
12417	Land Combat System I (LCS-I), USACDC ILC, Nov 70.
12634	Nuclear Warfare Operations 1970-75 (NUWAR) USACDC ILC, Nov 69.
12634	War Games Nuclear Warfare Operations 1970-75 (NUWAR), USACDC ILC, Nov 69.
12655	The Army Calibration Program.
12757	Secondary Armament for the Main Battle Tank (MBT-70).
12944	CDCEC Experiment 71.4, Exploratory Examination in Night Operations with Available Night Vision Devices, June 1968.
13105	CDEC Experiment 21.9, XM-19 Evaluation, June 1972.
13114	Court Reporting in the Army in the Field.
13208	Application of the CASSARS Simulation to an Evaluation of the Scheduled Supply Concept (Phase I).
13233	Troop Test, Land Navigation Systems (GAN/MAN), 1971.
13313	The Chaplain's Role as Related to Soldier Motivation.
13359	Conversion of FORTRAN Assembly Programs (FAP) to A.
13361	Determination of Procedures to Insure Continuity of CS_3 Automatic Data Processing Operations Within the Army in the Field, 1970-1975, (short title: CS_3 CON OPS) Vol I Final Draft Report.
13547	Cost Effectiveness Study and Trade-off Analysis for CS_3.
13708	TACFIRE Cost Effectiveness Study.
13921	Examination of the Logistical Support Operations for an Independent Brigade.

ACN	TITLE
13964	Integration of Direct Support (DS) Aviation Maintenance Units.
13966	Satellite Communications Potential for Army 1975-85 Study, 5 Feb 69.
13986	Dynamics of Fire and Maneuver (CDCIAS)
14055	Project HIGHGEAR, USACDC ILC, Aug 68.
14118	CDCEC Experiment 72.8, Southeast Asia Night Operations Ground (SEANITEOPS-GROUND), 15 May 1970.
14309	Prevention and Control of Communicable Diseases of Animals.
14689	Analysis to Identify Non-Divisional TOE Combat Service Support Units Requiring Magnetic Ledger Card Systems.
15137	Support of Airmobile Operations through Destruction of Enemy Air Defense Systems.
15353	CDCEC Experiment 71.5, Field Evaluation High Gear, June 1969.
15724	Optimum Mix of Artillery Units (1975-1980) (LEGAL MIX IV).
15758	ASARS I, Army Small Arms Requirement Study, Vol IV, June 1970.
15961	CDEC Experiment 11.6, Fire Effectiveness Evaluation: SHILLELAGH Missile/105-mm APDS, June 1969.
16043	Systematic Integration of Training & Doctrine (SITAD).
16149	Program Change Request (PCR) for Tactical and Support Vehicles; and Compendium of Doctrinal Basis for High Mobility Vehicles for Forward Area Unit.
16277	Tactical Satellite Communications (TACSATCOM) Cost Effectiveness Analysis, 6 May 69.
16430	Responsibility for Developing and Documenting Logistics Procedures.

ACN	TITLE
16494	Cost Effectiveness Analysis for Food Service System.
16495	Family of Army Vehicles Study (FAVS) Vol 1 and 2.
16710	Examination of Modified ASTRO Mechanized Infantry Division.
16819	STANO II, Part I Test, Fort Bragg, N. C., Dec 69.
16872	STANO Systems Assessment Model Scenario 1A Initial Report, USACDCSAGp TR 6-71, October 1971.
16914	Troop Test, M60A1 Add-on Stabilization System, 1972.
16975	Airborne STANO Systems, Part II, Test.
17018	Antitank Weapons Systems Requirements Study.
17036	MASSTER III Test Report, Vol II, MASSTER, Fort Hood, Texas, Oct 71.
17050	Tank Company STANO Subsystem Test, May 72.
17073	Aircraft Refueling and Rearming in Forward Areas (Short Title: FARR) 2 Vol.
17255	Tire Repair/Retread Doctrine.
17271	CDCEC Experiment 32.1, Ability to Adjust Artillery on Moving Targets, May 1970.
17781	CDEC Experiment 42.9, Precision Position Locator System (PPLS), June 1971.
17939	Support of An Air Mobile Division (SAM).
17408	Tactical Satellite Communications (TACSATCOM) Cost Effectiveness Analysis Study, 15 Apr 71.
17494	Development of a Divisional War Game Model, Vol II, December 1971.
17617	USACDCEC Field Experiment 43.5, Basic Attack Helicopter Team (BAHT), February 1971.

ACN	TITLE
17874	Mechanized Rifle Company STANO Subsystem Test, Mar 72.
17964	A Const/Logistics Analysis of Disposable and Nondisposable Eating Utensils in a 12-Division Theater Army Force
17964	TOE Manpower Authorization Standards and Criteria for Warehousing
19764	Cost/Effectiveness Analysis of Honeycomb Airdrop
18170	CDEC Experiment 42.10, Optimum Flight Profile, AN/UIH-6(V) Public Address System (ALOUD), August 1971.
18171	CDCEC Field Experiment 43.6, Attack Helicopter - Daylight Defense, Interim Report, December 1971.
18288	CDCEC Field Experiment 32.2, Artillery Versus Moving Target Follow-on (REACT), July 1972 (Interim Report).
18490	Field Evaluation of the Modified Army Strategic and Tactical Reorganization Objectives (ASTRO) Mechanized Division in Mid-Intensity Environment, 1971.
18728	STANO Survey and Review (STASAR), Nov 71.
18837	OTE FAAR Phase I, Apr 72.
N/N	CDCEC Experiment 65.2, FIR MAN, DDC #AD-383257L, Jan 65.
N/N	Commanders' Surveillance and Target Acquisition Information Needs (CSTAIN), 1972-76, Mar 72.
N/N	MASSTER Improved Acoustic Locator System Test Report, Vol II, 22 Mar 72.
N/N	Personnel Risk and Casualty Criteria for Nuclear Weapons Effects, USACDC Nuclear Agency, 2 Aug 71.
N/N	CDEC Experiment 21.13, LIVFIR Methodology, September 71.

OTHER STUDIES AND ARTICLES

A Compendium of Design Considerations for Counterinsurgency (COIN) Aircraft, AFIT Technical Report, 1969.

A Model for Cost Effectiveness Evaluation of Counterbattery Target Acquisition Systems, Cornell Aeronautical Laboratories, Report No: 1GG 20801-D-38-04, dated 29 November 1965.

AMCQA-113, System Effectiveness Status Report (Pershing) 10 Feb 72.

A Study of Measures of Effectiveness Used in Naval Analysis Studies; Ultrasystems, Inc., Newport Beach, California, 1st Year Report, 29 February 1972.

Base Measures for Comparing the Effectiveness of Conventional Weapons. Rand Corp No: RM 4647 PR, Jan 66.

Candidate Measures of Effectiveness for Air Strike Systems, Naval Weapons Center, China Lake, California, September 1969, NWC No. TP 4687.

LD 19678B. Effectiveness Analysis of Equipment Mixes for Engineer Units, pp. 213-219.

Exercise HELL TANK, UK Ministry of Defense, Defense Operational Analysis Establishment, Memorandum No.2/69, dated Jan 69 (S).

Measuring Combat Effectiveness of a Forward Area Reconnaissance/ Surveillance System. General Dynamics/Corvair Corp. No: ERR-AN-845, 31 Dec 65.

Parametric Design/Cost Effectiveness Study for a Mechanized Infantry Combat Vehicle-1970. Cornell Aeronautical Laboratory Report No: GM 2144-H-1a, November 1966 (US Army Weapons Command Contract: DA-11-199-AMC-651 (U)).

Proceedings of the Third NMC System Performance Effectiveness Conference, 1967.

Project ATTACK - Casualties as a Measure of Loss of Combat Effectiveness - World War II Experience, John Hopkins University No: ORO-T-289.

Small Independent Action Force, Vertex Corp., Nov 71.

"Some Aspects of a Comparison of Shipboard Cranes and Burtoning Gear in Service," Recent Research in Maritime Transportation, National Academy of Sciences, National Research Council, Publication #592, pp. 111-113.

Study of Weapons Effectiveness Assessment Concepts, Air Force Armament Laboratory, Air Force Systems Command, Elgin Air Force Base, Florida, Technical Report AFATL-TR-67-54, May 1967.

"Survival Effectiveness for Hardened Facility Systems," John J. Healy, Proceedings of the Tenth Annual US Army Operations Research Symposium.

"Systems Approach to Effective Documentation," Recent Research in Maritime Transportation, National Academy of Sciences--National Research Council, Publication #592, pp. 91-110.

The Domain of the Ground Effect Machine (The Determination of Physical and Operational Characteristics of Military Overland, Amphibious, and Marine GEMS from World-Wide Environmental Criteria), Office of Naval Research, Contract No: Non r 3375(00).

The Value of Life in Combat Risk Situations: a feasibility study. American University, 30 September 1968.

TECHNICAL REPORTS

A THEORETICAL BASIS FOR THE CONCEPT OF EFFECTIVENESS, William L. Harrison, Jr., United States Naval Postgraduate School Thesis, October 1966.

CONCEPTS ASSOCIATED WITH SYSTEM EFFECTIVENESS, E. L. Walker and Riley C. Horne, Jr., ARINC Research Corporation, Washington, D. C., Monograph No. 9, July 1960.

PREDICTING ERROR PROBABILITIES FOR A FUNCTION OF MEASUREMENTS BEFORE THEY ARE TAKEN, Helen D. Nelson, United States Army Electronics Command, Fort Monmouth, New Jersey, EDL-M1091, April 1967.

SENSITIVITY OF GROUND COMBAT MODELS TO WEAPONS MIXES, Sherburne Whipple, Jr., Research Analysis Corporation, McLean, Virginia, RAC-TP-377, December 1969.

TESTING, ANALYSIS, AND DECISION MAKING, F. A. Tatum, The RAND Corporation, Santa Monica, California, P-3107, AD 616726, April 1965.

THE APPLICATION OF STATISTICAL METHODS TO THE DESIGN AND ANALYSIS OF EXPERIMENTS, D. S. Stoller, The RAND Corporation, Santa Monica, California, P-646, AD 604645, March 1955.

THE ROLE OF DESIGN IN EXPERIMENTAL INVESTIGATION, Carl B. Bates, US Army Combat Developments Command Systems Analysis Group, Fort Belvoir, Virginia, TP-1-72, January 1972, AD 737688.

UNPUBLISHED PAPERS

A MATHEMATICAL THEORY OF MEASURES OF EFFECTIVENESS, by David L. Bitters, United States Army Combat Developments Command, 16 November 1970.

CONTROL ELEMENTS IN THE MEASUREMENT OF EFFECTIVENESS, HQ United States Army Combat Developments Command, 1971.

QUANTIFIED JUDGMENT METHOD FOR EVALUATING COMBAT EFFECTIVENESS FROM HISTORICAL DATA, Historical Evaluation and Research Organization, Dunn Loring, Virginia 1971.

THE COMBAT EFFECTIVENESS AND COST ANALYSIS - AN AID TO DECISION by David Hardison, United States Army Combat Developments Command Revised March 1968.

ANNEX B

INDEX OF TERMS

INDEX OF TERMS

ANNEX C

MATHEMATICAL REPRESENTATION OF THE HIERARCHICAL STRUCTURE OF MEASURES OF EFFECTIVENESS

ANNEX C

MATHEMATICAL REPRESENTATION OF THE HIERARCHICAL STRUCTURE OF

MEASURES OF EFFECTIVENESS

1. The appropriateness of selected measures of effectiveness depends upon the level of decision and level of objectives. Thus there is a hierarchy of measures of effectiveness for Army studies. These can be expressed in seven levels represented [1] functionally as follows:

(a) Political Level

E=a global measure of national security

$E=F(M_1,...M_i,...M_n)$

(b) OSD-JCS Level

M_i=measure of effectiveness of the i^{th} major mission (program)[2]

$M_i=G_i(e_1,...e_k,...e_n)$

(c) Service Command Level

e_k=measure of effectiveness of the k^{th} program element

$e_k=H_k(t_{11},...t_{i1},...t_{n1},...t_{1m},...t_{im},...t_{nm})$

1. Bonder, S., "Operations Research and Military Planning," 1971 (unpublished).

2. Since there exists multiple measures of the degree of mission accomplishments, an additional subscript should be appended to the M_i (and the other effectiveness measures used below) to reflect the existence of multiple measures of effectiveness. Thus M_{hi} would be the h^{th} measure of effectiveness of the i^{th} major mission. Explicit consideration will be suppressed for notational simplicity.

(d) Service Operating Level

t_{ij}=measure of the military worth (combat effectiveness) of units equipped with the j^{th} weapon system for the i^{th} combat task

$$t_{ij}=f_{ij}(y_{1j},\ldots y_{ij},\ldots y_{nj})$$

(e) y_{ij}=measure of the i^{th} performance capability of the j^{th} weapon system. (Cross-country speed, acquisition probabilities, hit probabilities.) These are the performance characteristics specified in a material needs document.

$$y_{ij}=g_{ij}(x_1,\ldots x_i,\ldots x_n)$$

(f) x_i=system physical characteristics (system gross weight, 1 i s center of gravity)

$$x_i=h_i(x_1,\ldots x_{i-1},\ldots x_n) \text{ for } 1\leq i\leq s$$

(g) x_i=component physical characteristics (component weight, x i c component dimensions)

$$x_i=l_i(x_{c+1},\ldots x_n) \text{ for } s<i<c$$

2. This Pamphlet, The Measurement of Combat Effectiveness, addresses with emphasis the 4th Level ( ) of the illustrated hierarchy. The "measure of military worth (combat effectiveness)" must be understood to have functional dependencies upon measures from the next lower level which in the above structure are level (e) as affected by level (f) as affected by level (g). (In this conceptual structure, F, G_i, H_k, f_{ij}, g_{ij}, h_i, and l_i are intended to denote functional dependencies at one level upon the measures listed from the next lower level.) In practice, these functional dependencies are implicitly represented by computerized combat models and simulations.

ANNEX D

THE PRINCIPLES OF MEASUREMENT OF EFFECTIVENESS

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THE PRINCIPLES OF MEASUREMENT OF EFFECTIVENESS

1. General. Even more difficult than the determination of cost -- which is difficult enough in itself -- is the problem of evaluating the effectiveness of conceptual land combat systems. Since the desired outcomes are deeply rooted in military values and military worth, it is most difficult to define them precisely. Nevertheless, the requirement exists to measure how well a proposed alternative land combat system or sub-system attains its goals. In Chapter 2 of this Pamphlet, the concept of measuring effectiveness was introduced as a process conducted according to some set of rules. In this ANNEX we are introducing a minimum set of these rules. To do this, we introduce some basic measurement theory and definitions relative to measures, in general, and MOE in particular.

2. Basics of Measurement.

a. Purpose of Measures. In the scientific process, measures are made of certain physical or chemical properties as means to achieve a goal. The goal is usually to make comparisons between like, similar, or perhaps unlike entities. The measures are in the form of numbers corresponding to a position on a scale (as on a pressure gage) or, as another example, in the form of counts of successive events (as on a tachometer). Almost never will such meter readings be the direct numerical values of the quantities in which we are interested. The actual quantities must be deduced by corrections and combinations of meter readings and calculations based thereon.

(1) The measurement of advances afforded by proposed land combat systems or sub-systems is similar to the measurement of advances in science and engineering. As an example, from a study and analysis of a land combat system, a generalized hypothesis is deduced which provides the basis for a new design, changed design, or changed design methods. The methods are used to design and to predict performance of the new system ... weapon, infantry platoon, armor battalion, etc... which may be different either in design or application from the system that provided the original data. Figure D-1 illustrates the process.

(2) Continuing the process and using a machine tool as an example, a new machine tool is usually first analyzed thoroughly for design prediction in performance. If the results agree with the design predictions, then the design can be accepted with some level of confidence. Likewise, the design methods may be used again for similar cases.

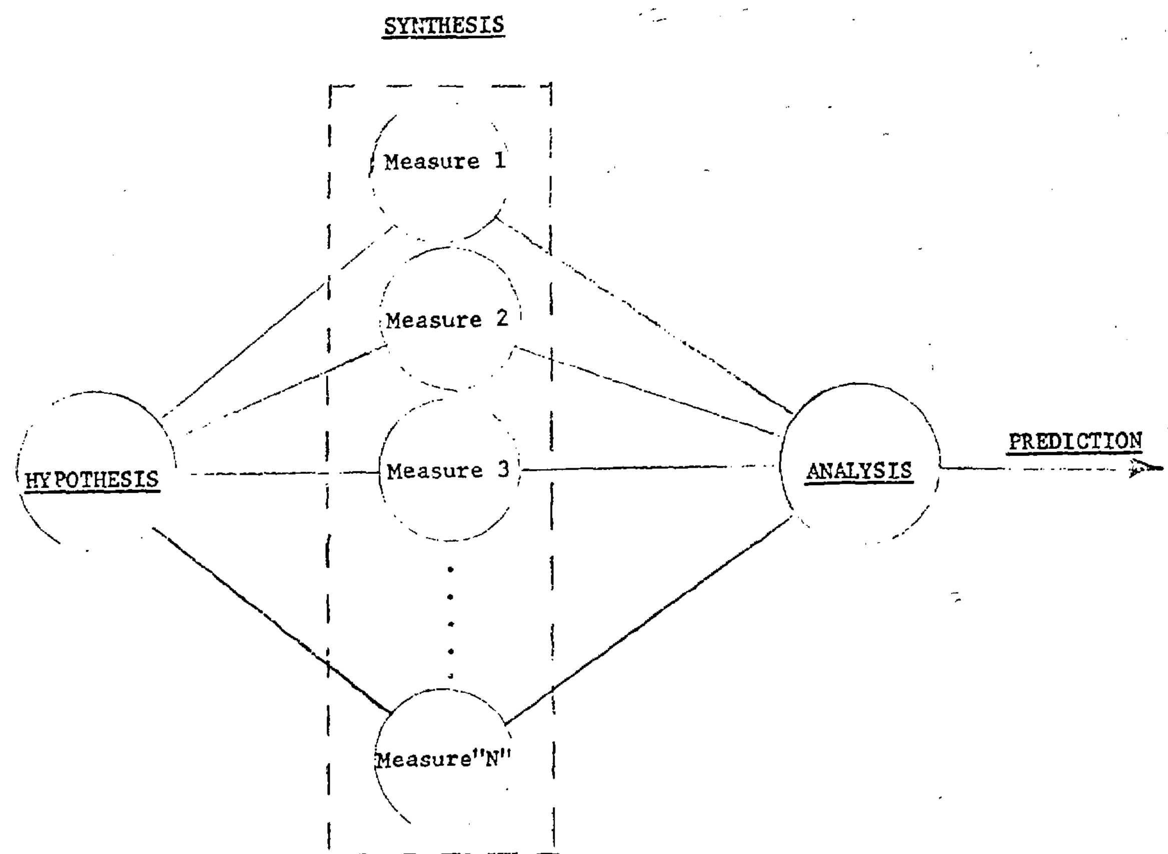

FIGURE D-1. THE SCIENTIFIC-ENGINEERING MEASUREMENT PROCESS

(3) The design method -- which corresponds to a theory in science -- acquires increased validity when a wide range of significant variables are a part of the original data, and are applied in diverse ways. For instance, the hypothetical example of a machine tool could be a new design lathe to automatically cut mill rough steel rod into finished close tolerance truck axles. The entire cutting process is to be computer controlled based on data evolved from manual methods used for cutting tool positioning, adjustments for cutting speeds, and depth of each succeeding cut. It can be easily seen that errors in the original data will result in erroneous design or design methods, or at least in the numerical factors involved.

b. Formulation of Measures. Measures are thus formulated to give certain information about the relations which hold between measurable properties associated with phenomena. In dealing with a phenomenon or group of phenomena the method is somewhat as follows: We first measure certain properties which we have some reason to expect are of importance in describing the phenomenon. The properties we measure may be of different kinds, and for each different kind of property we have a different role of operation by which we measure it: that is, we attempt to associate the property with a number. Having obtained a sufficient array of numbers by which the different properties are measured, we search for relations between these numbers. If we are skillful and fortunate, we find relations that can be expressed in mathematical form. We are usually interested preeminently in one of the measured properties and try to find it in terms of the others. Under such conditions we would search for a relation of the following form:

$$X_1 = f(X_2, X_3, X_4, \ldots \text{etc.})$$

Here X_1, X_2, etc., stand for the numbers which are the measures of particular kinds of physical properties. Thus X_1 might stand for the number which is the measure of effectiveness of an armor column, X_2 might stand for the number which is the measure of the movement capability of the armor column, X_3 the number of tanks in the column, etc. By shorthand statements we often abbreviate this description into saying that X_1 is effectiveness, but of course it is not; it is a number that partially measures effectiveness and is called a "measure of effectiveness." In terms of the definition of MOE in Chapter 1, X_1 expresses how well the armor column achieves its assigned task in a specified combat environment.

c. Dimensionality of Measures. Fundamental to the understanding of the measurement of effectiveness process is an understanding of the quantities and system of units used for physical measurement. In measurement, the first observation one makes with regard to the functional relation like the above -- $X_1 = f(X_2, X_3, X_4, \ldots \text{etc.})$ -- is that the parameters X_i fall into two groups, depending upon the ways in which the values of the parameters are obtained physically. The first group of quantities are called "primary quantities" which according to dimensional definition are fundamental and of irreducible simplicity. The primary quantities are the following: MASS, LENGTH and TIME. The measurement of combat effectiveness is analogous to the ordinary system of mechanics (i.e., the branch of physics that deals with motion and the action of forces on bodies). It is reasonable to conclude that the systems of measures of effectiveness use the same primary quantities of mass, length, and time. Figure D-2 shows an MOE analogy with physical measures. Measures of effectiveness are primarily secondary quantities that are combinations of certain primary quantities according to certain rules. For example, a velocity, as ordinarily defined, is a secondary quantity made up as a combination of the two primary quantities length and time.

$$\text{Velocity} = \frac{\text{distance traveled}}{\text{time to travel the distance}} = \frac{\text{length}}{\text{time}}$$

d. Inherent Errors in Measures. A major problem in the measurement of effectiveness is the problem of drawing conclusions in the face of possible error. This problem is identical to that of experimental physical sciences in which inferences are made from a set of experiments extrapolated to describe a larger class of "identical" or similar experiments that might be carried out. Figure D-3 shows three primary type of errors encountered in the measurement of effectiveness and the general causes for those errors. The following discussion is an expansion of Figure D-3.

(1) Random Error.

(a) The usual problem in evaluating candidate mixes of Army materiel and organization is to establish candidate mixes that are valid enough to be acceptable for decision. There occasionally may be no requirement for knowledge of the absolute magnitude of effectiveness, but there has to be an ability to compare amounts of changes in effectiveness. A good example that illustrates this has been the evaluation of surveillance, target acquisition, and night operations (STANO) systems. Devised mixes of STANO devices at organizational levels for evaluation, test, or experimentation are usually derived by varying types and numbers of STANO devices within the mix. Varying STANO mixes this way is good experimental procedure because the overall objective of STANO falls naturally into a determination that there is not only an increase (or decrease) in effectiveness as a function of STANO mixes but, of more significance, that there is a rate of increase (or decrease). This rate determination is needed because (as most evaluators now agree) STANO system configurations are continuums; i.e., they are configurations whose parts cannot be separately discerned as distinct unrelated elements. As such it is meaningless to expect that some precise mix will provide some precise effectiveness.

SCIENTIFIC CONCEPT	MILITARY CONCEPT	DEFINING EQUATIONS	
		SCIENTIFIC MEASURE	MILITARY MEASURE
FORCE	FORCE OF MOVEMENT	f = ma = mass x acceleration	f = number of troops x speed of troops per increment of time.
MOMENTUM	MOMENTUM OF FORWARD MOVEMENT	Mom = mv = mass x velocity	Mom = number of troops x distance traveled per unit of time.
PRESSURE	INDEX OF FIREPOWER	$p = \frac{f}{a} = \frac{\text{Force}}{\text{Area}}$	p = number of weapons x rate of fire per increment of time divided by the area of concentration.

FIGURE D-2. COMPARISON OF MOE AND SCIENTIFIC MEASURES

TYPE ERROR	DEFINITION	CAUSE
RANDOM ERROR	$M_i = f(\emptyset) + e(\emptyset, u)$ M_i = MOE $\emptyset$ = Performance Parameters u = uncontrolled variables $e(\phi, u)$ = error function	The assumption that knowledge of the behavior one or more performance parameters is, in fact, a true cause of the effect on the behavior of the system
SYSTEMATIC ERROR	$E[e/\emptyset]$, The expected value e given $\emptyset$.	The Built-In Bias in the Formulation of the MOE.
OBSERVATIONAL ERROR	Error of Omission or Commission.	The omission of a measure or the selection of a wrong MOE or a wrong scale of a MOE.

FIGURE D-3. INHERENT ERRORS IN THE MEASUREMENT OF EFFECTIVENESS

(b) Random error then can be defined to be all the variability, from whatever source, which exists among the results of independent trials of tests, experiments, or computer runs like those of the STANO mixes that are designed and thought to be identical. There may be error even though there is an apparent consistency in the results of the trials. The apparent consistency may be only evidence of small error, or it may be due to concealed off-balancing of large errors which may each be militarily significant when considered separately.

(c) As such, then, measures of effectiveness (MOE) fall into the classification of local inference, i.e., they are associated with the basic quantitative trial of the measurement of a single quantity. For instance, the problem of finding the velocity of light is one of local inference, whereas that of determining whether the velocity is or is not constant is a problem in the large. Or to use a military example: the problem of determining ammunition consumption rate is one of local inference.

(d) In terms of MOE, the local inference model is the following:

$$M = f(x) + e(x,u)$$

when M represents the measure of effectiveness, f(x) represents the dependence on x of the "true" quantity we wish to measure, e(x,u) represents the uncontrolled variables which cause the difference between the "true" quantity and M.

(e) The objective of an MOE is to make explicit statements about the relationship of M to x. The word "relationship" means any connection which has the property that M can be predicted more reliably and with greater understanding if one knows at what value of x it is made. Whatever x may be, the military analyst is interested in knowing whether there is a cause-and-effect relationship between x and M. Even after a mathematical relationship has been established, the question of a true cause-and-effect still remains open.

(f) The fact that knowledge of x helps us predict M does not necessarily mean that x is, in fact, even a partial cause of M. The difficulties involved in the measurement of effectiveness in the most subtle cases, however, provides us no excuse for errors in the simpler ones. Many of the difficulties come from lack of understanding of the difference between trials in which x is controlled and those in which it is merely measured. It helps to have the quantity f(x) considered to belong to the population of interest when the error function, e(x,u), and hence M, varies from one observation to another. This will be discussed in more detail regarding the risk in the measurement later in this ANNEX.

(2) Systematic Error. Systematic error is defined to be the bias in the trial or test. It can be described to be a function $E[e/x]$: the expected value e given x. Sometimes the words "accuracy" and "precision" are used to describe the extent of systematic error and random error, respectively. In the process of formulating MOE by using a functional relationship connecting a number of arguments, it is an advantage to keep the number of arguments as large as possible. This will insure most comprehensive expression of the explicit factors upon which the measure depends. Unfortunately, however, one does not obtain something for nothing: as the number of arguments increases, the uncertainty in the predicted value of the MOE also increases due to the introduction of more sources of error.*

(3) Observational Error. Observational errors in measurement of effectiveness are usually made by omission or commission through inexperience or oversight. In order to appropriately answer the question of what variables to include in the formulation of a measure of effectiveness, a great deal of military experience is required. For instance, one might treat a problem of the contribution of firepower to combat effectiveness by resorting to a relationship that includes a formulation of ballistic effects and rate of fire. We must have enough background to be assured that the problem involves essentially no elements that are not treated by this formulation. We must know that certain aspects of the situation can be neglected, and that certain others can be essential - such as mobility, which is not a part of the indicated formulation. To know this we have to reach back through generations of experience concerning military operations. Those errors we classify as observational errors in the measurement of effectiveness are not always blunders but personal errors that can be minimized by resorting to military experience and training in land combat operations and in the theory of measurement. The selection of a wrong measure -- or a wrong scale of a measure -- is classed as an observational error similar in character to a mistake in reading an observation in a test or computer operation. Experience provides the observer with an insight that will give him a "feel" for the approximate values of his measurements before he takes them. Training hastens the experience.

e. Degree of Risk in Measures. There is always an element of risk involved in the selection and use of measures to use as projections of performance and effectiveness. There is risk due to the amount of time and effort allowed for the selection of the measures. And there is risk due to the incompleteness of the chosen measures to comprehensively describe the combat behavior of candidate systems.

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*See Bridgman's Dimensional Analysis, Chapters IV and V for an extended explanation, especially the II Theorem, Chapter IV.

(1) For instance, it is unrealistic to expect combat effectiveness to correlate closely with performance norms from materiel tests done by laboratory engineers and technicians. Even so there is possibility of establishing a mean probable error which can be used as a baseline to compare field performance of candidate systems. As an example, it could be that predictors for night vision devices can be evolved both for the devices in STANO mixes and for the soldier operators of the devices. Measurements leading to percent target detection at different ambient light levels, at various distances, at various times to detect, and at various angular segments of target areas can lead to estimated performance effectiveness of the night vision devices with error probabilities at predetermined confidence levels. This is another way of saying that, when there are repeated trials such as in test and experimentation, or the exercise of probabilistic models, a degree of risk can be estimated statistically. After a group of measurements are completed the job remains to summarize the results in terms of the objectives of the measurements and then generalize from these to cur conclusions concerning a system's overall combat effectiveness.

(2) How do we accomplish the generalization and how do we measure the uncertainty involved in the generalization? There are various statistical methods that can be used depending upon the study objectives. One method is a confidence statement, a device particularly suited to general scientific purposes. Another method is significance testing a special case of statistical hypothesis testing which has some specific disadvantages relevant to effectiveness measuring. These two methods are simplisticly discussed in the following parts of this section, along with a third method which is analysis of variance. Full and complete description of these techniques is beyond the scope of this pamphlet but there are many good references to consult.* The operations analyst must be conversant with these techniques, for it is his responsibility not merely to measure effectiveness but also to assess the validity of his measures.

(3) Statistics has been defined as "decision-making in the light of uncertainty (or random variation)." Statistical inference refers to the process of inferring something about a population (e.g., the totality of all trained Army personnel of a specific type MOS which will be produced) from a sample, say ten, randomly selected from that population. Because in practice it is either impossible or impractical to investigate and analyze total populations, we obtain sample statistics (e.g., the estimated mean $\bar{x}$) and make inferences about population parameters (the true mean μ).

*A good basic text is Freund "Modern Elementary Statistics" or a more advanced text is Brownlee "Statistical Theory and Methodology in Science and Engineering." Both of these are listed in ANNEX A.

(a) Confidence Statement. Statistical inference may be broadly classified into two categories, estimation and hypothesis testing. Statistical estimation consists of two types, point estimates and interval estimates. Interval estimates provide more information than do point estimates in that interval estimates also provide a measure of the precision of the point estimate. An interval estimate is usually given as a confidence interval or confidence limits, the latter being lower and upper values of the confidence interval. For example, in the probabilistic statement:

$$P(A < \mu < B) = 1 - \alpha$$

A and B are the lower and upper, respectively, confidence limits for μ, (B - A) is the confidence interval for μ, and the degree of confidence that the limits do in fact encompass μ is the confidence coefficient, $(1 - \alpha)$. Although the most common values of $1 - \alpha$ used in practice are 0.90, 0.95, and 0.99, these values are completely arbitrary. Studies involving missile reliability often use confidence coefficients of 0.999, 0.9999, or even greater. Naturally, it is desirable that $(1 - \alpha)$ be as close to unity as possible, while at the same time (B - A) be as narrow as possible. Unfortunately, these are conflicting objectives and a compromise between the confidence coefficient $(1 - \alpha)$ and the width of the confidence interval (B - A) has to be made. For example, to be 100 per cent sure, $(1 - \alpha)$ must be 1 and the resulting confidence interval will be of the type $(-\infty, +\infty)$ which is of no practical value whatsoever. In other words, we can be as sure as we want, but the surer we are, the less we have to be sure of. For example, consider the sample (6, 8, 10, 12, 14) whose mean is $\bar{x} = 10$. The 90, 95, and 99 percent confidence intervals for μ are:

$$P(7.0 < \mu < 13.0) = 0.90$$
$$P(6.1 < \mu < 13.9) = 0.95$$
$$P(3.5 < \mu < 16.5) = 0.99$$

The proper interpretation of confidence intervals cannot be over-emphasized. One does not say that the probability is $(1 - \alpha)$ that μ lies between A and B. Rather, one is $(1 - \alpha)$ percent confident that (B - A) contains μ.

(b) Significance Testing.

(1) Moving now to the second category of statistical inference, hypothesis testing, the role of hypothesis testing in the decision-making process is discussed. A statistical hypothesis is an assumption about the population being sampled. A test of a hypothesis is a rule by which a hypothesis is either rejected or not rejected. Because hypothesis testing is based on sample statistics, the decision is always subjected to possible

error. The two types of errors in hypothesis testing are defined and illustrated below:

Type I Error (α) - The null hypothesis (H_0) is rejected when it is in fact true.

Type II Error (β) - The null hypothesis (H_0) is not rejected when it is in fact false.

	True Situation	
Decision	Null hypothesis is true	Null hypothesis is false
Reject null hypothesis	α	No error
Do not reject null hypothesis	No error	β

(2) The hypothesis being tested is termed the null hypothesis, and the hypothesis against which the null hypothesis is being tested is the alternative hypothesis. Tests may be either one-sided or two-sided, depending upon the alternative hypothesis. For example, the null hypothesis H_0: $\mu = \mu_0$ may be tested against one-sided alternative hypotesis H_A: $\mu > \mu_0$ or against the two-sided alternative hypothesis H_A: $\mu \neq \mu_0$. The two hypotheses, H_0 and H_A, are formulated during the development of a test procedure and reflect the hypothesis being tested and the magnitude of the difference from the null hypothesis which is desired to be detected.

(3) As with the commonly used confidence coefficients in interval estimation, the commonly used significance levels (α), e.g., 0.05 or 0.01, are completely arbitrary. Also as with interval estimation, we have conflicting objectives, that both types of errors (α and β) should be a minimum. However, for a fixed sample size, a decrease in either type error will increase the other type error. If we want to decrease both α and β, we must increase the sample size. What constitutes

suitably "small" values of α and β is not a question which can be answered unequivocally for all situations. The selection of α and β depends on the specific situation and should be governed by the consequence of the two errors, (1) rejecting a true null hypothesis and (2) not rejecting a false null hypothesis.

(4) During the development of a test procedure, a test statistic is selected and a critical value (say $\bar{x}_c$ for a one-sided test) is determined by using the two predetermined acceptable risks, α and β.

(5) The test statistic is then computed and compared with the critical value. If the test statistic falls in the rejection region (is $\geq \bar{x}_c$), the null hypothesis is rejected; if the test statistic is $< \bar{x}_c$, do not reject the null hypothesis. Figure D-4 includes some of the significance test methodology that is appropriate to MOE, is available, and can be referred to in statistical textbooks.

(6) As can be observed from Figure D-4, the significance test is qualitative rather than quantitative. In dealing with quantitative variables, it is often wasteful to point an entire analysis, test, or experimentation toward determining the existence of an effect when there is no evidence to decide whether the effect is large enough to be important. A confidence statement, when it can be made, contains all the information that a significance statement does, and more.

3. <u>Analysis of Variance</u>. The statistical approach to analyzing data is based on the axiom that there is no such thing as an exact measurement. This is not meant to be a reflection on the ability of the measurers, but a recognition of the fact that over and above measurement error, there are a vast number of uncontrolled factors that are present in the data. The uncontrolled factors introduce variation into successive measurements made at the same datum point.

a. The statistical quantity that measures variation is called the variance, and one of the basic analytical techniques is called analysis of variance. This consists of splitting out portions of the overall variance into parts that can be attributed to certain of the effects of the factors. An illustrative example of such a breakout would be, for instance, the analysis of two different mixes of sensor systems in night operations. The mixes could consist of different amounts of night vision devices, radar, and just plain "eyeball." The breakout would be the variances of the detections per eyeballs, per night vision devices, and per radar.

TEST	IN THE FORM OF
CONCERNING PROPORTIONS	p = some specific proportion or p ≠ some specific proportion
DIFFERENCE BETWEEN PROPORTIONS	$p_1 = p_2$ or $p_1 \neq p_2$
CONCERNING MEANS	u = some specific mean of measures or u ≠ some specific mean of measures.
DIFFERENCE BETWEEN MEANS	$u_1 = u_2$ or $u_1 \neq u_2$

FIGURE D-4. SOME APPROPRIATE STATISTICAL SIGNIFICANCE TESTS IN THE MEASUREMENT OF EFFECTIVENESS

b. In the context of hypothesis testing there is an investigation of one of two levels of a single factor. If more than two levels of a single factor, or if more than one factor is involved, the analysis of variance (ANOVA) procedure is appropriate for comparative analyses. The proper beginning of an ANOVA, however, is the designing (planning) of an experiment* and monitoring the conduct to assure that execution conforms to the experimental design. Then with complete information concerning the design and conduct of the experiment, a proper ANOVA model can be determined and a valid analysis of variance performed.

c. The analysis of variance is a method of partitioning the total variability of a response variable (measure of effectiveness) into its component parts. The partitioned component parts are associated with the controlled factors (weapon type, range, terrain type, etc.) under investigation and the uncontrolled random error. For example, suppose we have two controlled factors in an experiment - (1) Weapon Systems A, B, and C, and (2) Ranges 1000, 2000, 3000, and 4000 meters. The three systems (A, B, and C) and the four ranges (1, 2, 3, and 4000 meters) are called levels of the respective factors, Weapon Systems and Ranges. Weapon System is a qualitative factor, and Range is a quantitative factor. Suppose further that the objective of the experimental investigation is to compare the effectiveness of the three systems at the four ranges. Because all three levels (A, B, and C) of one factor (System) are combined with all four levels (1, 2, 3, and 4000 meters) of the other factor (Ranges), the experiment is termed a factorial experiment. "Factorial" is merely another word for "crossed." Because no a priori information is available, it is necessary to replicate (repeat) experimental trials a number of times at each of the 12 factor level combinations. (Each of the factor level combinations should, in general, be replicated the same number of times.) Replication is necessary in order to get an estimate of the uncontrolled random variation because it is the "experimental error" which provides the "yardstick" for measuring differences among the factors under study (Weapon Systems and Range). Replication makes a statistical test of significance possible. An additional function of replication is precision improvement, because the variance of a mean is inversely proportional to the sample size.

d. Because the uncontrollable errors in measurements adjacent in time or space tend to be correlated, randomization of the order of conducting the experimental trials is necessary. This is essential because the underlying theory to the analysis which will be ultimately applied to the experimental data is that the measurement errors in each of the experimental measurements are independent. Randomization additionally provides insurance against biased experimental results in that it gives all the possible uncontrolled influencing variables an equal chance to favor or degrade each system.

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*Here experiment can mean computer runs of a model, a field simulation, or the playing of a War Game.

e. Finally by proper application of local control, (balancing, blocking, and grouping of experimental trials), discriminations may be improved by reducing the uncontrollable random variability. This reduces the size of the systems' differences which are detectable from the comparative analyses of the experimental data.

f. Having properly applied the above three principles (replication, randomization, and local control) during the design of the experiment and assured that the conduct of the experiment adheres to the design, the appropriate analysis of variance model can be hypothesized and a valid ANOVA performed. The ANOVA model for the above described experiment is:

$$y_{\alpha\beta\rho} = \mu + A_{\alpha} + B_{\beta} + AB_{\alpha\beta} + R_{\alpha\beta\rho}$$

where y is the response variable, μ is the true mean effect, A is the Weapon System effect, B is the Range effect, AB is the interaction effect between the two factors, and R is the uncontrolled experimental error. This model is a "fixed" model because all levels of each factor were selected for experimentation. Consequently, inferences from the analyses results will apply to only the three Systems (A, B, and C) and the specific four ranges tested. If, on the other hand, the levels of each of the factors had been randomly sampled, the model would have been a "random" model. In this case inferences would be with respect to the parent populations from which the levels were randomly sampled. Crews or Days are examples of controlled factors in which interest would be in the parent populations from which the specifically tested Crews and Days were sampled. If both fixed and random factors are present in the ANOVA model, it is termed a "mixed" model.

g. Using the analysis of variance model and all experimental design information (interrelationship of the factors, order of experimentation, method of choosing factor levels, and all underlying assumptions of the model), an analysis of variance can be performed. This is accomplished by determining degrees of freedom, sums of squares, and mean squares for all right-hand terms, except the constant (μ), of the ANOVA model. Then from derived expected mean squares, appropriate F-ratios can be determined, hypotheses tested, and the desired comparative analyses performed.

h. In addition to factorial experiments, we may have nested experiments in which the levels of one factor are chosen within the levels of another factor. Moreover, we may have nested-factorial experiments which involve both factorial and nested factors. The complexity of the ANOVA model, naturally, increases with the complexity of the experimental design since the design dictates the ANOVA model. The analysis of variance is a powerful tool for performing comparative analyses if experimentaion is properly designed and conducted.

4. Specifics in the Measurement of Effectiveness. The basic theory of measurement was discussed in the previous section of this ANNEX relative to measures of effectiveness. The specific characteristics of MOE are discussed in this section.

a. Fundamental Consideration. Combat effectiveness measurement may be represented separately as an average over the total set of combat situations which includes friendly unit capabilities, enemy, environment, mission, all other factors in the combat situations and the probability that the combat situations are encountered.

b. Rules for Formulating MOE.

(1) A MOE has an Objective which is in Consonance with the Level of Objectives of the Analysis. A central problem in defining a measure of effectiveness is the frequent difficulty in determining whether a proposed measure is truly an important indicator of effectiveness or merely an indicator of performance. The difficulty lies not in semantics but in the understanding of relationships and objectives. Confusion is increased by views from different perspectives. For example, the designer or project manager of a helicopter views dash speed as an effectiveness measure. This is not necessarily the case for the combat developer who may view dash speed only as a contributor to the effectiveness measure of avoiding casualties in combat. In the measurement process, certain types of measurements have significance only at a specific level of decision. To give an example, the output effectiveness of a particular lathe in a machine shop is significant to the shop manager. The plant manager, however, is not interested in the unique performance of one particular type of machine tool in one particular shop. His interest is in the output of all machine tools of all shops in his plant in terms of total production and rate of production and the profit made. It is agreed that the effectiveness of one machine tool may have an influence on the aggregate; but even so, the plant manager's sole decision criterion may rest on whether the product can be profitably manufactured at all. Analogously there is a hierarchy of MOE evolved from a hierarchy of levels of decision. For National Defense the hierarchy is that shown on Figure D-5, and mathematically presented in ANNEX C. A general rule in this hierarchy is that MOE at a next lower level are performance parameters at the next higher level. The choice of MOE to be used at a given level of the hierarchy is determined by the measures used in the next level above. The actual values in a given measure are supplied as functions of measures from the next level below. For example,

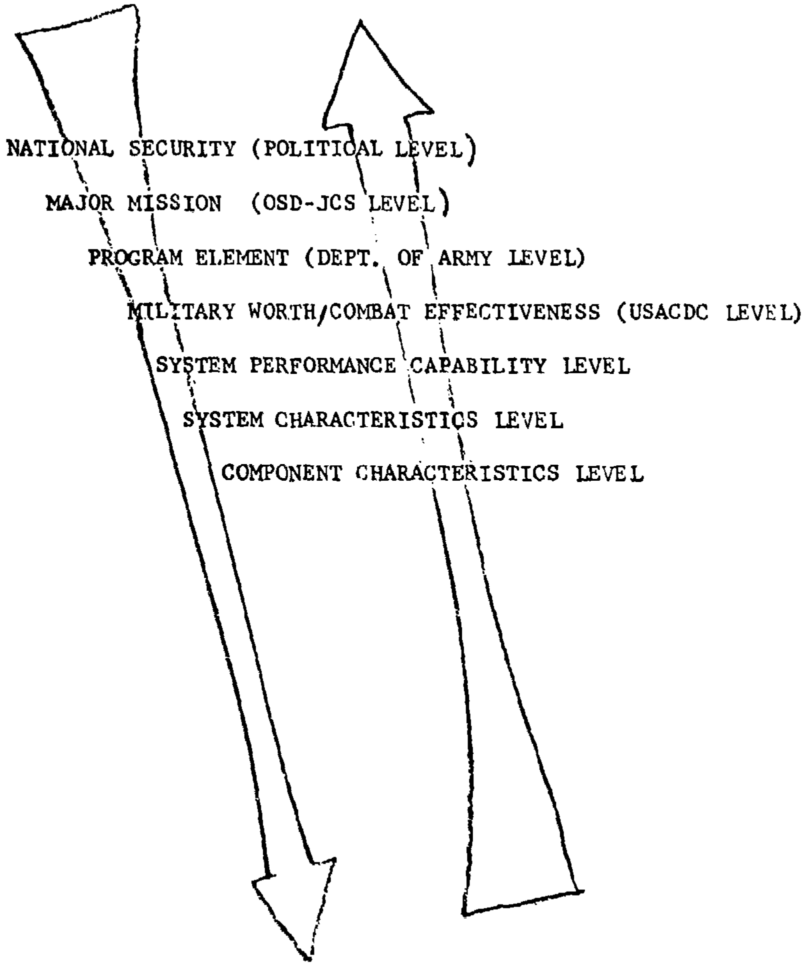

FIGURE D-5. THE HIERARCHY OF MEASURES OF EFFECTIVENESS

"Red Loss Exchange Ratio" is measured by the number of Red combat units killed divided by the number of Blue combat units killed. The actual numerical values of this exchange ratio, which is at the Combat Effectiveness Level, is a function of the weapon system performance at the next level below -- the System Performance Capability Level. This factor could be the target acquisition accuracy of the Blue combat units as well as the probability of a kill given a Blue tank engagement. The appropriateness of the exchange ratio to a land combat developments study depends upon the measure of effectiveness to be applied at the Force Effectiveness Level (DA) such as the ability to seize and hold ground in a projected conflict.

(2) A MOE is objective or subjective. MOE fall into two general categories: objective or subjective. The distinguishing differences between these are discussed below:

(a) Objective MOE. In the process of measurement of effectiveness it is desirable to compare the merits of competing systems by expressing the combat consequence implications caused by differences between the candidate systems. It is most desirable to do this my means of an objective set of numerical indicators -- measures of effectiveness -- derived from a measuring scale and coherent in a system of quantities and units as discussed in the theory of measurement. Occasionally the interaction of a system at issue with its parent supersystem and supporting subsystem are relatively simple and definite, and the measures of effectiveness can be explicitly stated in numerical form. Figure D-6 shows examples of MOE in numerical form.

(b) Subjective MOE. More often than not, because consequences cannot be quantified, the evaluation of the merits of several candidate systems cannot be mechanistically accomplished. A systematic appraisal, nevertheless, is still required. This is accomplished by using subjective judgement regarding comparative worth against some standard value. Adjectival evaluation, such as "good," "poor," "excellent," "average," belong in this category.

(3) There are classes of MOE depending upon use and scale. Measures of effectiveness may take many forms but there is a classification of the forms. Figure D-7 shows the classification and gives examples. Although not rigorous definitions, as a general rule, the four forms of measurement are identifiable by the arithmetic calculations typically associated with them. Ratio measures are characterized by division and multiplication. For example, rate of advance is obtained by dividing kilometers by days, and may be applied in multiplying rate of advance by days available for the operation. Interval measures are characterized by subtraction and addition. For example, time to refuel is obtained by subtracting start

MOE_1	#RED ELEMENTS KILLED/#BLUE ELEMENTS KILLED
MOE_2	#RED ELEMENTS KILLED/#BLUE ELEMENTS STARTING ENGAGEMENT
MOE_3	#RED ELEMENTS SURVIVING/#BLUE ELEMENTS STARTING ENGAGEMENT
MOE_4	#BLUE ELEMENTS SURVIVING/#BLUE ELEMENTS STARTING ENGAGEMENT

(INITIALLY: 10 BLUE ELEMENTS AND 25 RED ELEMENTS)

CANDIDATES	MOE_1	MOE_2	MOE_3	MOE_4
A	2/2 = 1.0	2/10 = .2	23/10 = 2.3	8/10 = .8
B	20/10 = 2/0	20/10 = 2.0	5/10 = .5	0/10 = 0
C	8/2 = 4/0	8/10 = .8	17/10 = 1.7	8/10 = .8

QUESTION: WHICH CANDIDATE IS THE MOST COMBAT EFFECTIVE?

FIGURE D-6. EXAMPLES OF MOE IN NUMERICAL FORM

TYPE OF MEASUREMENT SCALE	TYPICAL USE
NOMINAL	NON RANKING IDENTIFICATION
ORDINAL	POINT ON A DEFINITE SCALE
INTERVAL	A SPREAD ON A DEFINITE SCALE
RATIO	ORDER-RANK COMPARISON

FIGURE D-7. CLASSIFICATIONS OF MOE TYPES time from end time, and may be added to travel time to obtain turn-around time, but is not ordinarily multiplied or divided by anything. Ordinal measures are characterized by rank ordering. A commander may prefer offense to defense to retrograde, but would not ordinarily attempt to add or subtract their degrees of desirability. Nominal measures are characterized by categorizing into sets. A unit may be classified as infantry, armor, or artillery, but types of units are not ordinarily rank ordered.

(4) MOE have to Involve a Sense of Worth or Importance. Rational choice often goes beyond measure and scale; such choices involve, too, a sense of worth or importance, and, thus, an additional dimension of value. This can often be treated by the assessment device called "weighting" in importance associated with a rank ordered scale like most important .... 1 .... least important .... 10 .... in a 1 to 10 scale. Figure D-8 is an example of such a weighting scheme. The weights used in this figure are purely arbitrary. The illustration shows that the weighting can be done between elements within a function of land combat as well as between functions. The importance of weighting is that it brings to bear the experience that represents many generations of exposure to military operations in practice. It, in some way, formulates reliability and relations between parts in land combat functions. This point is discussed in more detail in Chapter 3 and ANNEX E.

c. Principle Rules for Constructing MOE.

(1) A Constructed MOE Should Provide Additional Information. In developing measures of effectiveness it is important that each measure contribute additional information to the solution of the problem. If a Measure B is a consequence only of Measure A, then B will not furnish any additional information. At times, however, it may not be immediately clear that one MOE is a consequence of another, expecially, in the case where a composite measure is made up of several MOE. The important thing to remember is to have the quantities and units of the measure consistent, i.e., not to mix "apples and oranges," as it were. Otherwise, the mathematical operations in constructing composite MOE -- adding, subtracting, multiplying, dividing of measures with other measures, or combinations -- will have no really useful meaning. The problem of discerning meaning in an MOE is most troublesome in the development of MOE indices. Figure D-9 shows two examples that have been used in past studies which indicate the degree of difficulty that can be encountered.

EXAMPLES OF MEASURES	EXAMPLES OF ELEMENTS WITHIN THE MEASURE	EXAMPLES OF WEIGHTING THE ELEMENTS	EXAMPLES OF WEIGHTING THE MEASURE CATEGORY
MOBILITY	TIME TO SETUP. TIME TO TEARDOWN. AVG CROSS. COUNTRY SPEED. . etc.	1 3 5 . . .	1
FIREPOWER	RATE OF FIRE. BLUE TO RED KILL RATIO. . etc.	5 1 . .	5
INTELLIGENCE/ ACQUISITION	PROBABILITY OF DETECTION. PERCENT OF POTENTIAL TARGETS ACQUIRED. . etc.	2 1 . .	3
COMMAND/ CONTROL	MEAN SPAN OF CONTROL. AVG TIME TO DISSEMINATE ORDER. . etc.	1 3 . .	7
COMBAT SERVICE SUPPORT	PCT OF SUPPLY REQ'S FILLED. OPERATIONAL READINESS. MEAN TIME TO REPAIR. MEAN EVACUATION TIME. etc.	3 1 2 5 . . .	10

FIGURE D-8. WEIGHTING MOE.

MEASURE	DEFINITION EQUATION OF THE MEASURE	CRITIQUE
Military Worth Index	$\sum_{i=1}^{i=n} MW_i \times Pd_i$ MW = a number assigned to target i as an assessment of its relative worth. Pd = probability of damage to target i.	At times in a fire fight it is conceivable that the probability of damage to a target is that the assessment of worth of the target causes heavier concentration of fire on the target. Furthermore, the probability of damage to a target does not necessarily measure the effectiveness of a weapon system. When the mission is to take or hold a forward position, target damage alone, regardless of the estimate of worth of the target, is not enough of a measure.
Mobility Index (Tracked Vehicles)	$E = \frac{CPF \times WF}{TF \times GF} + BF\text{-}CF \times EF \times TF$ E = relative mobility index CPF = lbs/sq in. of track in contact with the ground. WF = gross weight in lbs *TF = trackfactor, inches/100 *GF = height of grouser, in. BF = (bogie gwt. lbs) (number of bogies in contact with ground) (area, sq in. per track shoe) EF = horsepower per ton *TF = transmission factor *Expressed as factors.	The index ignores in its units all of the elements in the basic definition of mobility which are: (1) capability of being moved or transported quickly, and (2) capability of being moved or transported with ease. The MOE appears to treat the second but not the first element, assuming that ground pressure, height, horsepower, and transmission factors meet the minimum criteria, not stated. Speed as a measure of "quickly" does not appear in the formulation, but needs to be in order to meet the full definition of mobility.

FIGURE D-9. EXAMPLES OF INCOMPLETE MOE AS INDEXES

(2) A Composite MOE Should be Constructed According to Structural Laws. The process of rank ordering is the essential ingredient in the measurement of effectiveness. The method is to establish or use a mathematical theory or algorithm by which one can rank-order alternative systems. The use of measures is to represent an empirical structure by a similar in type (analogous) or similar in form (homomorphic) numerical structure. For instance, the suggested analogy of MOE to certain laws of physics was discussed in previous parts of this ANNEX and illustrated in Figure D-2. It is this use that leads to construction of measurement scales. We are all familiar with the process wherein we can compare things qualitatively by weighing them on a scale, such as a chemical pan balance. We then empirically order them by using the numerical ordering of the scale values (weights in grams). Using this scale, putting two objects together is then represented by adding their weights. It is thus that a set of empirical relations leads to construction of measurement scales and is called a measurement structure.

(3) An MOE Can be Constructed According to Empirical Military Laws. Certain empirical laws of military science yield measurement structures akin to the qualitative structures underlining fundamental measurement in physics. They are worth pursuing in the development of MOE. The possibility was touched upon in the discussion centering around Figure D-2, Analogy of MOE and Scientific Measures. In addition to those implicitly shown in the Figure, there are those such as the well known Circular Error Probable (CEP), or the "slope of learning curve" as applied to the first ... second ... third day's operation ... etc, or to the "rate of attrition in a closed duel" of the Lancaster Equations. Not much has been done along these lines of MOE development, but further pursuit holds a great deal of promise.

5. Summary.

a. A MOE is a measure usually expressed as a number that is based on the following three principles:

(1) A measure is valid when it measures what it is supposed to measure.

(2) A measure is reliable when it measures something accurately and consistently.

(3) A measure is both valid and reliable when there is knowledge of the type and degree of error present in the measurement.

b. The process of the measurement of effectiveness follows the scientific measurement process formulating certain information about relations which hold between measurable properties associated with a phenomenon. The method is somewhat as follows: In the formulation of the measure we first list those properties we have reason to believe are of importance in describing a phenomenon that fits our objective. The properties we measure may be of different kinds; when they are, we have different operations by which we measure them to associate the properties with numbers. When we believe we have a sufficient array of such numbers we search for relations between the numbers. If we are skillful and fortunate, we then find that the relations can be expressed in mathematical form.

c. In this ANNEX we have found that there are certain characteristics that MOE need to possess:

(1) There must be an objective for the measure which is at a specific level of the objectives for the analysis.

(2) The measure must adhere to systems and units such as those used in physical measurement which includes classes and scales for particular uses.

(3) The measure, when composited, needs to be structured according to useful, rigorous, and interpretive structural laws.

(4) The type and degree of error in the measure must be formally stated as well as the degree of risk.

(5) The measure is an estimate based on certain sets of givens, and it entails a certain sense of qualitative worth within the analysis.

d. In Chapters 3 and 4, these characteristics are clearly delineated by illustration of the development and application of MOE in combat developments. Chapter 3 essentially covers techniques and discussion covering the basis of the techniques. Chapter 4 has many examples of MOE that have been used or could be used for combat developments studies.

ANNEX E

A HYPOTHETICAL EXAMPLE OF STRUCTURING MOE TO FIVE FUNCTIONS OF COMBAT

A TECHNIQUE FOR DERIVING AND EVALUATING MOE

1. Where to Start. While no one would deny the need for creative thinking and military judgement in developing MOE, in the practical situation one sometimes welcomes some sort of starting point for brain-storming. This pamphlet does not espouse any rigid procedure for thinking and judgement, but can offer a structured approach that has been applied in some combat developments studies. In this technique, the place to start is at the top; and the technique is essentially to break the system's purpose into progressively lower sub-divisions of objectives until characteristics of effectiveness sufficiently narrow are obtained that quantitative measures can be applied directly. This results in a branching, tree-like structure with a large number of characteristics to be measured at the furthest points of the structure. At that point one turns to the matter of selecting which MOE should be applied.

2. Application of the Technique. The first step is to consider the purpose of the system under evaluation, to divide the purpose into its objectives. Next, the objectives are then divided into all their possible parts, and these lower level divisions are further divided into yet lower parts, until every part of the system's purpose has been broken down to the point where an operation has been defined so narrowly that a measure virtually suggests itself. At each step two judgements are made: first whether all possible subdivisions are included, and second, whether any of the divisions are directly measureable. For example, if the system is a whole Army unit the purpose is to conduct land warfare operations, and the objectives at the first level of division may be the five functions of land combat: intelligence, command-control-communications, firepower, mobility, and combat service support. These five objectives are so general that none of them can be measured directly. On the other hand, if "the system" is an airborne reconnaissance system, its purpose may be to acquire targets and its objectives the detection, identification, recognition, location, and hand-off of targets. In this simpler system, it would appear that at least one of the first levels of division is directly measurable: Target location effectiveness could be measured in terms of mean error, mean offset error, or circular error probable of reported loactions. Returning to the more complex system, the next step is to divide each of the five functional areas of land combat into subobjectives of the system. Combat service support, for example, might be divided into supply, transport, maintenance, and medical support. At the same time, the other four functional area objectives (intelligence, command-control-communications, firepower, and mobility) are similarly divided into system subobjectives.

The first question at this level is whether all relevant subobjectives have been included. If the evaluated system is below Division level, it may be reasonable that supply, transport, maintenance, and medical support fully subdivide the combat service support objective. If the system under consideration were a theater-level system these would probably not exhaust the subobjectives of combat service support. The second question is whether any of these four subobjectives is directly measureable. It would probably be decided they are not because each of these is still too general to measure directly. At the next level of breakdown the supply function might be divided into completeness, timeliness, and accuracy of meeting supply requests. If it is agreed that these three characteristics fully define supply support effectiveness, then the second question is whether any of them are directly measurable. The system's effectiveness has been so narrowly characterized at this point that it may be decided that direct measurement is practical. Completeness of meeting supply requests, for example, might be measured in terms of percentage of supply requests met and proportion of requested supplies provided. Timeliness might be measured as percent of supplies delivered by time requested and mean-time-to-resupply. Accuracy of supply support might be measured in terms of numbers and types of supplies delivered versus requested. In like manner, all five of the functional areas would be progressively subdivided to the point of measurement. The end result of this procedure is a branching structure starting with the system purpose at the top and ending with numerous measureable characteristics at the bottom.

3. Representation of the Analysis. If the system has any complexity at all, it would probably require several persons with different backgrounds working over some period of time to complete the breakdown. During this time it would aid communication to have some sort of diagrammatic representation of the structure; this might also aid thinking. During the process a worksheet such as the one in Figure 3-5 in Chapter 3 might be useful. At the end of the process the final breakdown could be expressed in branching form like Figure 2-1 in Chapter 2. When the chart is complete, its bulkiness can be alleviated by expressing both the measures and their weights in symbolic notation, as in Figure 3-6 in Chapter 3. (This figure is reproduced here as Figure E-1.) Figure E-1 is a convenient representation of the structure, simplified to only a few measures for illustration.

4. Selection of MOE. The complete structure would be expected to result in too many characteristics to measure. Some would be deleted because they are not independent of other measures included. Others would be deleted because it is not feasible to measure them within the constraints of a particular study. In any case, MOE would be deleted that do not meet the criteria for validity or reliability. After deletions it may be necessary to revise the structure to ensure the remaining MOE cover all elements of system effectiveness.

RED THREAT → INTEL/ACO

BLUE CAPABILITY → MANEUVER, FIREPOWER, CMD & CONTROL

ENVIRONMENT → SUPPORT

	INTEL/ACO	MANEUVER	FIREPOWER	CMD & CONTROL	SUPPORT
Weighted MOE for A Functional Area (How the Candidate System Performs.)	$W_{11}\ A_1$ $W_{12}\ A_2$ ⋮	$W_{21}\ M_1$ $W_{22}\ M_2$ ⋮	$W_{31}\ F_1$ $W_{32}\ F_2$ ⋮	$W_{41}\ C_1$ $W_{42}\ C_2$ ⋮	$W_{51}\ S_1$ $W_{52}\ S_2$ ⋮

$$W_{11}A_1 \oplus W_{12}A_2 \oplus \cdots W_{21}M_1 \oplus W_{22}M_2 \oplus \cdots W_{31}F_1 \oplus W_{32}F_2 \oplus \cdot\cdot W_{41}C_1 \oplus W_{42}C_2 \oplus \cdots W_{51}S_1 \oplus W_{52}S_2 \oplus \cdots$$

Combat Effectiveness of a Candidate System

$$E = \mu_1 A \oplus \mu_2 M \oplus \mu_3 F \oplus \mu_4 C \;..\oplus \mu_5 S$$

DECISION

$D = E \oplus$ JUDGEMENT OF THE IMPACT OF "UNMEASURABLE" FACTORS

TERMINOLOGY

W_{ij} = Military judgement weight for the importance of MOE_i in Functional $Area_j$.

A_r, M_e, F_m, C_n, S_p = Sets of MOE in various Functional Ares (Expressed as Blue/Red ratios).

μ_j = The Decision Maker's weights of importance for Functional Area.

FIGURE E-1 FRAMEWORK OF A COMBAT SITUATION WITH APPLICATION OF MOE

5. Testing the MOE. The structure with its MOE, weights, and rules for combining MOE values has to be tested in some manner to be confident that the selected MOE result in a viable overall statement of effectiveness. Testing the MOE must address three questions.

a. DOES THE STRUCTURE ADEQUATELY MEASURE THE INDIVIDUAL MOE?

(Can be answered by examining assumptions underlying the structure's use and the accuracy of the structure's input data.)

b. WHAT MOE ARE NOT ADDRESSED BY THE STRUCTURE?

(A measure of this deficiency in the structure can be given by the sum of W_{ij} for the measures not evaluated.)

c. WHAT IS THE ESTIMATED IMPACT OF UNMEASURABLE FACTORS?

(One way is to reduce the decision maker's judgement factor assigned to the Functional Area j. This adjustment will result in a lower E for the candidate system.) The first of these questions, examining the underlying assumptions, may be given a trial by assigning plausible MOE values to the structure and then performing the combination steps to see if the output is credible and discriminates among alternatives. Figure E-2 is an example. It is a simplified test of the structure of a land combat system shown in Figure E-1. Two to four MOE are inserted into Figure E-1 for each of the five functional areas. Hypothetical values for weights and for MOE scores of three alternative sytems are assigned, and combination rules are established for each of the two levels represented. In this example all raw scores are normalized by dividing each of the three candidate scores for a measure by the highest of the three scores for that measure, resulting in a score between zero and one for each alternative on each of the fifteen measures. The MOE within a function are combined by calculating the product of the normalized scores for an alternative system and then taking its n-th root. That is, if two scores are combined, the function score is the square root of their product; if three scores are multiplied their cube root is taken; and if four scores are multiplied the overall function score is the fourth root of their product. Thus, the range of values for an overall score for a functional area lies between zero and one. In this example, the rule for combining the five overall functional area scores is to simply sum their weighted objective scores. In the example it is seen that this structure differentiates among the three candidates but preserves the fact that they performed very nearly equally on most measures. It is most important to note that this structure, in its

ACQUISITION/INTELLIGENCE	MANEUVER	FIREPOWER	COMMAND & CONTROL	SUPPORT
$W_{11}A_1$ W_{11}=.33 A_1 =Pct of Tgts Detected .33 {70% = 23, 85 = 28, 50 = 17} * {.82, 1.00, .61}	$W_{21}M_1$ W_{21} = .25 M_1 = Rate of Advance .25 {10 KPH = 2.50, 12 = 3.00, 15 = 3.75} * {.67, .80, 1.00}	$W_{31}F_1$ W_{31} = .10 F_1 = Nr Rds Expended .10 {2,500 Rds = 250, 2,600 = 260, 2,400 = 240} * {.96, 1.00, .92}	$W_{41}C_1$ W_{41} = .50 C_1 = Reciprocal of Mean Time FM Receive Msn to Issue Order .50 {1/2.4 Hrs = .208, 1/2.7 = .135, 1/2.3 = .217} * {.96, .85, 1.00}	$W_{51}S_1$ W_{51} = .33 S_1 = Pct Supply Req's Met .33 {80% = 26, 70 = 23, 90 = 30} * {.87, .77, 1.00}
$W_{12}A_2$ W_{12} = .33 A_2 = Proportion Tgts Correct Identification .33 {.90 = .30, .95 = .31, .80 = .26} * {.97, 1.00, .84}	$W_{22}M_2$ W_{22} = .50 M_2 = Pct Force Reach Obj .50 {80% = 40, 85 = 43, 70 = 35} * {.93, 1.00, .81}	$W_{32}F_2$ W_{32} = .30 F_2 = Pk given Hit .30 {.10 = .030, .11 = .033, .09 = .027} * {.91, 1.00, .82}	$W_{42}C_2$ W_{42} = .50 C_2 = Reciprocal of mean Nr of changes per order. .50 {1/3 per = .167, 1/4 = .125, 1/2 = .250} * {.66, .50, 1.00}	$W_{52}S_2$ W_{52} = .33 S_2 = Veh Opn'l Availability .33 {90% = 30, 80 26, 95 31} * {.97, .84, 1.00}
$W_{13}A_3$ W_{12} = .33 A_3 = Reciprocal of mean time to Acquisition .33 {1/14min=.024, 1/10 =.033, 1/18 =.018} * {.73, 1.00, .55}	$W_{23}M_3$ W_{23} = .25 M_3 = Mean dispersion Dist .25 {400M = 100, 300 = 75, 500 = 125} * {.30, .60, 1.00}	$W_{33}F_3$ W_{33} = .20 F_3 = Reciprocal of mean time to Fire Mission .20 {1/20sec=.01, 1/20 =, 1/20 =} * {1.00, 1.00, 1.00}		$W_{53}S_3$ W_{53} = .33 S_3 = Reciprocal of Mean Med Evac Time .33 {1/8min = .041, 1/9 = .037, 1/7 = .047} * {.87, .79, 1.00}
		$W_{34}F_4$ W_{34} = .40 F_4 = Loss Exchange Ratio .40 {3/1 = 1.2, 2/1 = .8, 1/1 = .4} * {1.00, .67, .33}		

GEOMETRIC: nth root of product of weighted, normalized scores

$\mu_1 A$	$\mu_2 M$	$\mu_3 F$	$\mu_4 C$	$\mu_5 S$
$\mu_1 = .15$ $A = \left[\left(\frac{W_{11}A_1}{*}\right)\left(\frac{W_{12}A_2}{*}\right)\left(\frac{W_{13}A_3}{*}\right)\right]^{1/3}$ {.60, 1.00, .28} $\sqrt[3]{}$ {.84, 1.00, .65} .15 {.13, .15, .10}	$\mu_2 = .20$ $M = \left[\left(\frac{W_{21}M_1}{*}\right)\left(\frac{W_{22}M_2}{*}\right)\left(\frac{W_{23}M_3}{*}\right)\right]^{1/3}$ {.50, .48, .81} $\sqrt[3]{}$ {.79, .78, .93} .20 {.16, .16, .19}	$\mu_3 = .30$ $F = \left[\left(\frac{W_{31}F_1}{*}\right)\cdots\left(\frac{W_{34}F_4}{*}\right)\right]^{1/4}$ {.87, .67, .25} $\sqrt{}$ {.97, .90, .71} .30 {.29, .27, .21}	$\mu_4 = .20$ $C = \left[\left(\frac{W_{41}C_1}{*}\right)\left(\frac{W_{42}C_2}{*}\right)\right]^{1/2}$ {.63, .43, 1.00} $\sqrt{}$ {.79, .66, 1.00} .20 {.16, .13, .20}	$\mu_5 = .15$ $S = \left[\left(\frac{W_{51}S_1}{*}\right)\left(\frac{W_{52}S_2}{*}\right)\left(\frac{W_{53}S_3}{*}\right)\right]^{1/3}$ {.73, .51, 1.00} $\sqrt[3]{}$ {.90, .80, 1.00} .15 {.14, .12, .15}

* Divided by the highest score of the three alternatives, for normalization

$E = \mu_1 A + \mu_2 M + \mu_3 F + \mu_4 C + \mu_5 S$

$E_1 = .13 + .16 + .29 + .16 + .14 = .88$
$E_2 = .15 + .16 + .27 + .13 + .12 = .83$
$E_3 = .10 + .19 + .21 + .20 + .15 = .85$

FIGURE E-2

present state of development, does not explicitly reflect dependencies which may exist among MOE in different functional areas or threshold values for particular MOE required to be reached by any candidate system. Any other combination rules that have some empirical basis might be used. The geometric combination is used here because previous research indicates that arithmetic combination does not preserve sensitivity to large changes in individual MOE values. The technique described in this section is merely one possible technique of deriving candidate MOE, selecting useful ones, representing the analysis process conveniently, and testing it. Other means of aiding creative thinking and military judgement may be better in particular situations.

ANNEX F

INDEX OF MEASURES OF EFFECTIVENESS

DOCTRINE

ORGANIZATION

MATERIEL

LOGISTICS

TRAINING

COMMAND, CONTROL AND COMMUNICATIONS

FIREPOWER

MOBILITY

INTELLIGENCE

COMBAT SERVICE SUPPORT

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