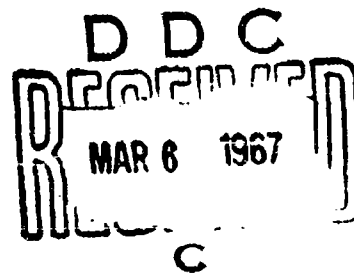# CAN OPERATIONS RESEARCH CONTRIBUTE

TO LOGISTICS RESEARCH?

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INTRODUCTION

One principal mission of the Assistant Commandant for Logistics Research and Doctrine assigned by the Commandant and published in the Organizations and Functions Manual of the USALMC is:

> "To serve as principal assistant to the
> Commandant on all matters pertaining to
> logistics research and doctrine development."

Each action officer assigned to the Department supports the research mission. This pamphlet is designed to acquaint newly assigned officers with the dynamic field of Operations Research and to encourage individual study to discover the many tools and techniques available which will facilitate the task of Logistics Research.

Operations Research

1. Historical Background: While the roots of Operations
Research (OR) are as old as science and the management function,
its name dates back only to 1940. The first applications of
Operations Research on an appreciable scale were made by Great
Britain and the United States in World War II. Operations
Research methods helped to solve a broad range of military prob-
lems. Typical of these were the determinations of convoy size,
fuse settings of depth charges dropped from aircraft against
submarines, size of formations and techniques of bombing by air-
craft, methods of sea mining, search patterns in hunting ships
and submarines, and various radar detection problems. Generally,
Operations Research activity in these wartime projects related
primarily to the _uses_ of weapons and skill of the military
organization and only incidently to the design of the weapons
themselves.

Following the close of World War II, Operations Research
almost immediately became firmly established in British trade and
industry. In the United States, however, it was not until 1952
that Operations Research began to attain comparable status in
industry. Since that time, interest in the method has steadily
grown. At present, it is well established in the transportation,
chemical and aircraft industries. It has been used successfully
by one or more representatives of many other types of industry or

business, including banking, insurance, light and heavy metal manufacturing, food processing, and agriculture.

2. Operations Research defined:

a. Operations Research is a composite activity in that it makes use of concepts and techniques from many fields of knowledge. A review of the existing literature on Operations Research provides a variety of definitions usually varying only in detail. Generally, each definition contains the essential elements of the following statement:

"Operations Research is the application of scientific methods, tools and techniques to problems involving the operations of a system so as to provide those in control of the system with the best (optimum) solution to the problem."

The definition found in both JCS Publication 1, Dictionary of U. S. Military Terms for Joint Usage and AR 320-5, Dictionary of U. S. Army Terms is most applicable. These documents define Operations Research as: "The analytical study of military problems, undertaken to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations. Also known as operational research, operations analysis."

The military definition of Operations Research and the generally accepted professional definition have these common elements:

(1) Study of a problem(s)

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(2) Scientific method or basis

(3) Solutions

b. A review of these three elements indicate that the Operations Research approach to problem resolution has much in common with the time proven military "study" or "staff study." Both require isolation of the problem. Both employ the traditional scientific approach of observation, experimentation, analysis and comparison. Both produce a recommended solution. At what point then is Operations Research and the "staff study" method different? The major difference is in the tools and techniques used. The tools of the staff study include logical assembly of the facts, experience and judgment. Operations Research tools are based principally on mathematics. Many of the classical procedures are used separately or in batteries - algebra, calculus, differential equations, geometry, mathematical statistics, probability theory, etc. A resume of some of the accepted Operations Research tools and techniques are contained in Inclosure 1.

Logistics Research

1. We are interested in the means of obtaining increased use of Operations Research methods in accomplishing in-house logistics studies and in the evaluation of contractual studies. The purpose specifically is to relate Operations Research to research in logistics (as defined in AR 320-5).

2. Inclosure 2 outlines an approach to logistics

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research. In the past, logistics problems were studied by the technique shown in Column 1, identified as Military Analysis or the "Staff Study." Recent advances in Operations Research and Automatic Data Processing have made available two important tools to assist in the development of logical conclusions and recommendations to the Commander. The characteristics of the new tools are such that they complement the traditional approach, rather than substitute for it.

a. Operations Research (Column 2, Incl 2) is concerned with finding the best decision, policy or design. Analysis of operations has shown that if a pattern of regularity can be found in observed behavior, it becomes possible in many cases to measure interactions with the operation and thus to predict the effects of changes in it. This, precisely, is what Operations Research strives to do: To find the pattern of behavior and to predict the effects of changes in the operation.

b. The application of Operations Research or scientific research to logistics and business-type problems has shown unusual promise. The examples which follow are but a few that appear applicable to the field of logistics:

    1. Loading and scheduling transportation.

    2. Personnel requirements for "busy-quiet" work locations.

    3. Cafeteria scheduling.

     <u>4</u>. Plant location problems.

     <u>5</u>. Occupancy of facilities.

     <u>6</u>. Inventory control.

3. Automatic Data Processing: (Column 3, Incl 2): Operations Research makes much use of computers, not as a basic tool but as a source of power replacing human labor. Some Operations Research techniques involve such vast computation that only a power tool can do it economically. The power tool is the computer.

Tentative Conclusions

1. That logistics problems can be most effectively resolved by combining the features of the staff study with the tools and techniques of Operations Research and capabilities of ADPS.

2. That the combination of tools described in Tentative Conclusion No. 1 above comprise Logistics Research.

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TYPE TOOLS AND TECHNIQUES USED IN OPERATIONS RESEARCH

The material which follows is not intended to be all inclusive, but rather a general listing of tools and techniques that have been found useful in Operations Research.

1. STATISTICAL ANALYSIS

The term "statistics" is used as a general name for a large group of mathematical tools based on the laws of probability which are used to collect, analyze and interpret numerical data. These tools have been indispensable in the various fields of the physical and social sciences. In recent years they have been applied in some areas of engineering and management. In one of these areas - quality control - they have been adapted and applied with outstanding success. The application of statistical techniques is useful in the following ways:

a. Summarizing a mass of data to make it more useful for the problem at hand.

b. Ascertaining the degree of confidence one may have in information obtained by sampling.

c. Determining the number of observations that must be gathered for the required degree of accuracy.

d. Extracting the maximum amount of useful information from available data and observations.

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e. Appraising in specific terms the uncertainties of most situations.

f. Planning for the collection of data in such a way as to avoid the effects of bias.

g. Computing the probability of some specific event happening.

h. Collecting data so only necessary but balanced information is gathered.

i. Formulating and testing of hypotheses.

2. MODELS AND MODEL BUILDING

One of the major characteristics of Operations Research is the conversion of the problem to a model.

A scientific model is a representation of some subject of inquiry (such as objects, events, processes, systems) and is used for purposes of prediction and control. It is intended to make possible, or to facilitate, determination of how changes in one or more aspects of the modeled entity may affect other aspects, or the whole. In the employment of models, this determination is made by manipulating the model rather than by imposing changes on the entity itself.

There are three types of models: iconic, analogue and symbolic. The iconic model pictorially or visually represents certain aspects of a system, such as a photograph or model airplane. An analogue model employs one set of properties to

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represent some other set of properties, for example the flow of
water through pipes may be taken as an analogue of the "flow" of
electricity in wires. A symbolic model is one which employs sym-
bols to designate properties of the system under study (by means
of a mathematical equation or set of such equations). The sym-
bolic model is usually the most difficult to conceive and the
most general and abstract. Its function is more often explanatory
than descriptive. It is well suited to prediction or determination
of effects of changes on the actual system. The advantages of
manipulating a model rather than an "actual" object or process are
obvious.

3. SYMBOLIC LOGIC

Symbolic logic is a special process used in making models of
situations and their analytic manipulations in a very abstract
manner. Essentially, it involves sets of symbols which have
special meanings and indicate relationships that enter into
considerations of a problem. It is best described as a means of
expressing propositions and statements of relationships between
propositions in a concise and unambigious form. The uses of
symbolic logic, like the uses of mathematics, are not limited to
specific applications in a particular field. Just as the same
differential equation can describe the mechanical vibrations of a
physical system or the flow of electricity in a circuit, a symbolic
sentence can describe the conditions of a contract or the operation
of a computer element.

4. QUEUING THEORY

Queuing theory is sometimes referred to as the delay or waiting line theory. It is directed toward the study of the buildup of queues or waiting lines at a servicing facility, as related to the capacity and servicing characteristics of the facility and the demands for service. The queuing theory is not a single set of mathematical formulas but an expanding collection of methods and concepts based on a variety of assumptions. Some of the basic characteristics which may vary from problem to problem include:

a. Size of the group being serviced.

b. Whether the "customers" are "patient," i.e. will they stay in line indefinitely or not.

c. The distribution of servicing times, i.e. how long does it take to get service?

d. The characteristics of arrivals, i.e. uniform or random.

e. The number of servicing units.

5. THEORY OF GAMES

Game theory is the analysis of choice of strategies in a competitive situation. Problems arising in competitive games, warfare and business competition are equally open to analysis using this general theory of strategy. The essential problem in games theory is to choose a strategy in face of a conscious antagonist which will in some sense be "optimum." The three important concepts of the theory are the "mixed" strategy, the

role of bluffing, and the "mini-max principle." A mixed strategy is one in which the steps are taken by random choice within a definite probability distribution function. Bluffing is a form of mixed strategy. It merely complicates chance by attempting to lead an unwary opponent astray. The "good" strategy in game theory is the one based on the mini-max principle: that is, the one which makes the player's maximum expected loss a minimum. One principal use of the gaming theory is in solving problems related to planning.

6. MONTE CARLO TECHNIQUE

The Monte Carlo technique is applied frequently to simulations of the gaming theory approaches. However, Monte Carlo is not limited to gaming theory, but can be used in simulations of all types. It is used to predict the outcome of a series of events, each of which has its own probability. In many problems an analytic model may be too complex to manipulate. It may be possible, however, to construct a numerical model, with tabulated probability distributions, stated functional relationship, etc. A large number of trials of operating "on paper" with random draws from probability distributions, repeated with functions and distributions adjusted for changes in controllable parameters, can be used to trace out the dependence of outcome on parameter values. The Monte Carlo method is able to give at least approximate answers to many questions where other mathematical techniques fail.

7. LINEAR PROGRAMMING

Linear programming is best defined as a technique for determining the best allocation, or use, of limited resources to achieve some desired objective. There are many new applications of this technique, and many unexploited but obvious possibilities exist. Best locations for service facilities can be calculated by introduction of this technique of mathematics. Analysis of optimum routes for deliveries and the associated problems of the locations cf warehouse and factory sites are amenable to solution by this technique. The large amount of data, number of computational processes, and sheer bulk of the problem make it necessary to think of a computer when there is a linear programming analysis to do. Linear programming is one of the most powerful and broadly used techniques in Operations Research.

8. INFORMATION THEORY

Information theory is an analytical process transferred from the electrical communications field to Operations Research. It presumes to evaluate the effectiveness of information flow within a given system under study. Its most extensive utilization thus far has been its influence in stimulating the examination of organizational structures with the view to improving information or communication flow. Information is the basis of all man's activities and provides the means of communication and direction between humans, between humans and machines, and between machines.

There are two types of information that can be readily distinguished. One is pure scientific information and the other is what is called selective information. Scientific information is concerned with description of fact. For example, the formula H_2O represents information about the structure of water. Selective information concerns events which have a certain probability of occurring. Information theory is mainly concerned with this type of information, its coding and transmission.

9. OPERATIONS SIMULATION

This technique appears to have great promise in Operations Research. Uses of simulation have grown rapidly in recent years because of the availability of electronic computers. Early simulation studies attacked problems such as inventory problems, production scheduling systems, etc. Recently, this technique was used for the simulation of an entire logistics system for the Air Force. The important characteristics of the simulation technique are as follows:

a. Any number of variables can be handled. The only limitation is the computer's ability to handle the data.

b. The data to be processed can be empirically derived and do not have to be smoothed or changed into equation form.

c. The relationship between variables can be complex, i.e. linear restrictions do not have to be maintained.

d. The essential nature of simulation is that the model should

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vary in time, so that the process is a step-by-step re-enactment of the physical or qualitative system.

In addition to these technical characteristics, there are some additional general characteristics which should be noted. Because of the large amount of detail which can be built into a problem, simulation gives results which are useful for the particular system under study. Simulation while less valuable in discovering general laws, is useful to gain insight to specific systems.

Complex simulations are not practical without a computer, and are completely dependent upon the ultra high speed of electronic data processing. Thus, a significant characteristic of simulation lies in the computers ability to digest many years of dynamic operation which are expressed by the model and compress them into a few minutes of actual time. This makes possible the study of a variety of alternative paths into the future. The selection of the best path or policy may become obvious. But more likely the policy to be followed will require a great deal of judgment, and the simulation results aid in balancing one alternative against another.

APPROACH TO SOLVING LOGISTICS RESEARCH PROBLEMS

1	2	3
Military Analysis*	Operations Research**	Automatic Data Processing
1. Problem Definition	1. Analysis of Problem as defined in Column 1.	1. Support as required.
2. Assumptions if any	2. Assist in the development of valid assumptions if any.	2. Support as required.
3. Facts Bearing on the Problem: a. Research b. Interviews c. Observations	3. Assist in verification of results of research, interviews and observations.	3. Support as required.
4. Discussion: a. Analyze System Requirements b. System charting c. Experimentation d. Comparison e. Design of New System	4. Operations Analysis utilizing appropriate OR techniques. a. Develop model b. Derive a solution from the model c. Test the model and the solution derived from it d. Based upon the solution assist in design of new system	4. Operations Analysis Support a. Provide computer support for mathematical processes. b. ADP System design c. Program and code new system d. Test new system routines
5. Conclusions	5. Support conclusions	5. Support development of conclusions.
6. Recommendations	6. Support Recommendations	6. Support Recommendations

*FM 101-5, dtd July 1960

**Introduction to Operations Research; Churchman Ackoff and Arnoff - Wiley - 1957

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13. ABSTRACT

This pamphlet is designed to acquaint newly-assigned officers with the dynamic field of Operations Research and to encourage individual study to discover the many tools and techniques available which will facilitate the task of Logistics Research.

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