DECISION INFORMATION

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Preface

In a nation and a world in which per capita resources are shrinking, the quality of management control becomes increasingly important. Good management control, whether in making major decisions or in day-to-day operations, depends on good *decision information.* The present work is a collection of papers treating some features of the theory and application of decision information. The United States Department of Defense shares a general concern with decision information and provides the major motivation for this book.

In September 1976 the United States Air Force Office of Scientific Research sponsored a scientific workshop, Decision Information for Tactical Command and Control, held at the Airlie House in Airlie, Virginia. The other three military services joined the workshop as equal scientific participants. We (the editors) were members of the steering committee responsible for the administrative and scientific planning of the workshop.

One of the purposes of the workshop was to provide the scientific managers of the Service Office of Research with the knowledge that would allow them to formulate research programs relevant to military problems in decision information. Included was the presentation of scientific disciplines that have not previously been applied to such military problems but which have high promise of yielding useful results. Besides presenting current research, the workshop stimulated new research in the scientific community, both in new areas and in the application of current theoretical work.

In brief, four major objectives of the scientific workshop were identified: 1. *Problem Identification;* 2. *Enhancement of Interaction between Researchers and Managers;* 3. *Consideration of Operational Effectiveness Measures;* and, 4. *Stimulation of Relevant Research.*

The papers that were given at the workshop were published as presented under the title Proceedings of the Workshop on Decision Information for Tactical Command and Control. During the editing process, we felt, in view of the importance of the subject area, it would be a worthwhile project to undertake the present task. Approximately half of the workshop presentations were selected for inclusion in this book. These papers were refereed, and then appropriately modified. We have also included some invited contributions from scientists whose works complement the selected presentations from the workshop.

The monograph is presented in three main parts: *deterministic models, stochastic models, military models.*

The first part consists of presentations in *systems approach to large-scale human and man – machine systems, benefit – cost models for decision makers, team decision models,* and *cubic interpolation processes.* In these presentations the authors give attention to structuring various theoretical aspects of the models and also illustrate their scientific usefulness to many problems in our society.

The second part of this work consists of statistical models in the areas of *scheduling systems, combat models, logistic structures, inventory systems, Bayesian and empirical Bayesian reliability models, parameter estimation schemes,* and *memory models.* These presentations, which represent a broad spectrum of mathematical sciences, illustrate two main facts which make most problems difficult, namely, the numbers of variates in the model and the degree of uncertainty.

Part three is devoted to military presentations. However, a great deal of the basic philosophy and approach to the problems is applicable to various economic, engineering, and medical conflicts. We have included: *the problem in command, control, and communication; implementation of fuzzy sets in military command analysis; decision support in a conflict environment;* and *data-poor modeling.*

The presentations included in this book represent only a small selection of the vast amount of work in both deterministic and stochastic model building in mathematical sciences, but we believe them to be interesting, instructive, and applicable.

We would like to express our appreciation to the contributors that made this volume possible. Also, our sincere thanks to Major General Jasper A. Welch, Jr., Dr. William L. Lehmann, Dr. I. N. Shimi, and Lt. Col. R. A. Geesey from the United States Air Force for their kind assistance throughout the entire project.

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Robert M. Thrall
Chris P. Tsokos

Contents

PART THREE: MILITARY MODELS

Part One

Deterministic Models

SOME REMARKS ON THE CONTENTS OF PART ONE

In this part of the monograph we present five papers under the general classification of deterministic models.

The fifth paper presents a new numerical method for determining the optimum of a given, known function of one method. Although this is a classical problem it is useful to be reminded that there is still room and need for research in improving practical methods for extracting decision information from data even when it is organized in explicit functional form.

Since many major decisions are based on soft data it is clearly important to break away from the traditional academic emphasis on hard data models. The first four papers deal with the modeling process per se and the "softer" aspects of decision analysis.

The first of these considers potential applications of a general theory of living systems to military command and control. This general theory identifies seven levels of living systems: cell, organ, group, organization, society, and supranational system and relates these to each of nineteen critical subsystems. The first part of the paper provides a concise survey of the general theory and the last part treats briefly a number of potential military applications.

The second paper presents a model for translating human judgements into measurement scales. This model exploits the hierarchical character of systems and applies the Perron-Froebenius theory of positive matrices to obtain eigenvectors whose components may be regarded as measurements on ratio scales.

Decision information plays an especially important role in situations where a manager is faced with allocation of limited resources. The third paper introduces a multidimensional benefit-cost model which features the inclusion of non-economic benefits and costs. By tackling the crucial problem of merging

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hard and soft data this model can come closer to real decision situations than ones which attempt to cast all considerations into an economic framework.

The fourth paper begins with the team decision problems and constructs a decision rule which makes integral equations to optimize a team utility function which is axiomatically characterized. The authors point out that whereas the general case is difficult to solve there are several special cases where solutions are readily obtained. One such case, which is treated in detail, involves a quadratic cost function and the assumption of a uniform distribution for the price level and divisional price forecasts.

POTENTIAL APPLICATIONS OF A GENERAL THEORY OF LIVING SYSTEMS TO THE STUDY OF MILITARY TACTICAL COMMAND AND CONTROL

by JAMES GRIER MILLER, M.D., Ph.D.
President, University of Louisville

The "systems approach" is currently being applied to the solution of problems and the improvement of cost-effectiveness of many large-scale human and man-machine systems, both civilian and military. In many parts of the world this approach is respected as a useful way to deal with such matters. Many who regard it highly, however, are not entirely clear what the systems approach is.

A group of scientists with whom I was associated as director for about 20 years, first at the University of Chicago and later at the University of Michigan, began, in the 1950's, to use systems concepts to analyze biological and social systems. Our work was based to some extent upon information processing, cybernetic, and general systems concepts formulated by Ross Ashby, Norbert Wiener, Claude Shannon, and Ludwig von Bertalanffy who described principles that apply to concrete systems of all sorts, living and nonliving. From these conceptual approaches applied to findings of biological and social science we developed a general theory of living systems, an integrative approach to what is now coming to be called "systems science."

My book, Living Systems, presents the details of, and scientific evidence for, the general theory of living systems upon which our group reached essential agreement.[1] In it I deal with seven "levels" of living systems: cell, organ, group, organization, society, and supranational system. Each of these levels includes particular sorts of entities that exist in space-time. These are concrete systems rather than conceptual systems, abstracted systems of relationships, or abstractions. While

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each concrete system differs from all the others in such attributes as physical make-up, processes, and size, all share certain characteristics. Cross-level formal similarities or formal identities can be found among them. Analysis of these general systems characteristics can lead to better understanding of particular biological, social, and technological systems such as those involved in modern military command and control.

Some concepts that are basic to such analysis are summarized below:

System. The term system has a number of meanings. There are systems of numbers and of equations, systems of value and of thought, systems of law, solar systems, organic systems, management systems, command and control systems, electronic systems, even the Union Pacific Railroad system. The meanings of "systems" are often confused. The most general, however, is: A system is a set of interacting units with relationships among them. The word "set" implies that the units have some common properties, which is essential if they are to interact or have relationships. The state of each unit is constrained by, conditioned by, or dependent on the state of other units.

A concrete system is a nonrandom accumulation of matter-energy, in a region in physical space-time, which is organized into interacting, interrelated subsystems or components. The living systems are a special subset of the set of all possible concrete systems, composed of the plants and the animals. They all have the following characteristics:

(a) They are open systems, that is, they have boundaries which are at least partially permeable, permitting sizeable magnitudes of certain sorts of matter-energy or information to cross them.

(b) They use inputs of foods or fuels to restore their own energy and repair breakdowns in their own organized structure.

(c) They have more than a certain minimum degree of complexity.