Systems Analysis for Effective Planning

Principles and Cases

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Systems Analysis for Effective Planning: *Principles and Cases*

Bernard H. Rudwick

The MITRE *Corporation, Bedford, Massachusetts*
and Member of the Faculty
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Systems Analysis for Effective Planning

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Systems Analysis for Effective Planning: Principles and Cases

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SYSTEMS ENGINEERING AND ANALYSIS SERIES

In a society which is producing more people, more materials, more things, and more information than ever before, systems engineering is indispensable in meeting the challenge of complexity. This series of books is an attempt to bring together in a complementary as well as unified fashion the many specialties of the subject, such as modeling and simulation, computing, control, probability and statistics, optimization, reliability, and economics, and to emphasize the interrelationship between them.

The aim is to make the series as comprehensive as possible without dwelling on the myriad details of each specialty and at the same time to provide a broad basic framework on which to build these details. The design of these books will be fundamental in nature to meet the needs of students and engineers and to insure they remain of lasting interest and importance.

Foreword

An increasing emphasis in today's world is being placed on change and it is likely that attention to change will continue to grow in the future. The opportunity for change and the presence of uncertainty makes planning desirable and essential. Systems analysis for effective planning has been needed, particularly in the military, and much work has been done over the past decade or more to develop principles for carrying out effectively such analysis.

Experience gained in systems analysis of military systems has been valuable but costly. It is desirable that this sort of experience be presented to a broader readership and that the ideas gained be made available to others for use wherever such systems analysis for effective planning is not so well documented. Bernard Rudwick's book describes systems analysis principles and cases principally in terms of military examples where the major expenditures of time and effort have been placed; however, non-military uses are also indicated.

Rudwick has had many years of experience in developing and teaching the material presented in this book. He has illustrated many of the principles with practical cases which initially have much of the poorly-defined flavor of the real world. His important contributions are to recast the problem as given to make it the problem as understood, and to indicate methods for its solution.

Although many of the cases illustrated here have a military setting, the fundamental principles and methods are frequently applicable to non-military situations as well. Readers of this book will find much to benefit them from a study of the methods described. The principles are useful both in their original context as well as in a number of broadly related fields.

It has been a pleasure for me to work with Rudwick as he has developed and clarified his exposition of the ideas on systems analysis for effective planning.

HAROLD CHESTNUT

Preface

This book is about the application of systematic, quantitative methods and techniques to the task of planning. However, the principles covered here have such broad applications to the more generalized topic of problem solving that other descriptions of the topic might be helpful. These other descriptives might include the following:

1. How to plan for change, particularly technological change, in an organization.
2. A creative, systematic approach to the task of problem solving.
3. An efficient way of looking at problems in an attempt to obtain the preferred solution.
4. A method that can help a planner to convince others of the rationality of his proposal.
5. A method that can help a decision-maker to evaluate proposals effectively for change.

OBJECTIVE OF BOOK

This book closely documents a formal two-semester course entitled "Systems Analysis for Effective Planning," which has been presented a number of times at The MITRE Corporation and at Northeastern University's Center for Continuing Education. In general, the students were technical systems planners, systems engineers, or technical managers of planning groups. In addition, portions of the material have been presented at a number of university and defense courses on systems engineering and resource management.

The course, hence the book, was developed to meet the following observed needs:

Although much has been written on the philosophical or intellectual level regarding the need for systems analysis or cost-effectiveness analysis as part

of the systems planning process, there has been a lack of unclassified, methodological material which showed explicitly how to attack complex, unstructured problems involving choice among system alternatives.

It was felt that there is a lack of appreciation of the real problems which higher-level decision makers face in confidently making choices among alternate systems and the type of structured information they require.

Thus the objective of this book is to show the following:

1. There is a describable approach for dealing with complex problems involving high uncertainties.
2. This approach can and does provide much of the key information that decision makers need to choose rationally among alternatives.
3. That systems analysis can serve to sharpen the intuition of experienced system planners.
4. That despite its limitations systems analysis can be far superior to any alternative approach for making policy decisions.

AUDIENCE TO WHOM THIS BOOK IS DIRECTED

By bringing together the key principles and methods of systems analysis and showing how they are applied in representative cases of generalized interest, this book will be of interest to the following audiences: First, to those individuals currently engaged in systems planning who have not been exposed to a methodological presentation of how this work can be accomplished efficiently and who wish to improve their understanding of the formal process involved. This book should provide these planners with more systematic methods for creating more and better system alternatives, as well as a better understanding of how to relate the value of systems to the higher-level organization objectives.

Second, the material presented here should be of interest to managers or decision-makers who wish to have a better understanding of the quantitative methods and techniques of systems analysis so that they may see what information could and should be provided them by a trained systems analysis team located in their organization.

Third, the book should be of interest to systems engineering and other students who are interested in learning more about systems analysis or the "systems approach" before entering the systems planning field in either the defense or nondefense sector of the economy; it should also be of interest to university faculty who want to develop courses for providing such knowledge.

PHILOSOPHY OF PRESENTATION

The principles of systems analysis are relatively straightforward and, perhaps, deceptively simple. A listing of such principles might include the following:

1. Be explicit in all aspects of the analysis.
2. Determine the objectives of the job to be done.
3. Identify and attempt to quantify all of the key factors involved in the system and the job to be done.
4. Determine the complete economic implications of each alternative under consideration.
5. Conduct the analysis in an iterative fashion.

What may be difficult is the task of applying such principles to real problems. I believe that one can truly learn these principles only by grappling with real problems. Hence the teaching approach used in the course on which this book was based consisted of a presentation of key principles of systems analysis followed by a series of complex, lifelike problems used as a vehicle for reinforcing and showing how to apply these principles. Various techniques, such as probability theory, decision theory, and economic theory, are deliberately introduced on an "as needed" basis so that the need for the theory is established, the theory presented, and its application shown. This book has not been written as a customary reference book but more as a self-teaching document. Moreover, since principles are developed in a cumulative fashion, the book should be read completely for maximum reader utility.

Before presenting the overview of the approach to be followed, let me say something about the type of problem used to illustrate the principles discussed. For several reasons many of them are defense oriented. First, they are the problems with which I have been associated; second, they are complex and indicate the need for thorough analysis; third, in my opinion there is a need for a book that documents the detailed approaches used in analyzing defense oriented problems. I have attempted to cover a wide range of planning problems in the defense industry. For these reasons this book provides a double benefit to the defense oriented systems planner. As will be seen, however, these problems can be readily understandable to the nondefense planner. Moreover, as described in the overview, many of the same *classes* of problem also occur in the nondefense field and the same principles of systems analysis also apply. These classes include support systems such

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as information systems, maintenance systems, logistics, and spare-parts inventory systems as well as the general class of "flow systems" encountered in the analysis of manufacturing or distribution systems. Hence each chapter contains a description of the general principle(s) involved, the specific application of each, and a discussion of the generalized class of problem in which the same principle(s) can be applied.

There are many acknowledgments I wish to make for all the help received in preparing this book. First, I wish to thank the management of The MITRE Corporation, particularly Ken McVicar, for the encouragement and support he has given me. It should be noted that although I have drawn heavily on my experience at The MITRE Corporation in writing the book the contents reflect my own views and do not necessarily reflect the official views or policy of the Corporation or its employees.

Many others have been of help to me in this effort. In particular, I would like to thank my colleagues Jack Porter, Charles Godwin, Lee Morris, Martin Jones, Joseph Ye, William Marcuse, and Harold Glazer of The MITRE Corporation and Lieutenant Colonel James Blilie of the Electronic Systems Division of the United States Air Force for their review of all or parts of the book and the thoughtful comments they provided. I am also indebted to David Votaw for all of his comments on the treatment of the probability and statistics portions of the book and to Clare Farr, Nelson Briggs, Louis Perica, Jr., Pat Chatta, and Rosemary DeFusco, all from MITRE, for their help. My thanks also to Harold Chestnut and Donald Heany of the General Electric Company for my discussions with each which proved so helpful. A special thanks to Mrs. Joan Blanchard and Mrs. Barbara Olson for the excellent typing and all the painstaking efforts that were involved in assembling this manuscript with such skill, patience, and good humor and to Ted Cutting for his meticulous editing of proof.

Last I wish to acknowledge Robert McNamara, Charles Hitch, and Alain Enthoven for their foresightedness in conceiving the need for such analytical approaches to management and their abilities in being able to implement them to the extent that they did; for without these approaches this book could not have existed.

BERNARD H. RUDWICK

Lexington, Massachusetts
June, 1968

I

SYSTEMS PLANNING AND THE DECISION-MAKING PROCESS

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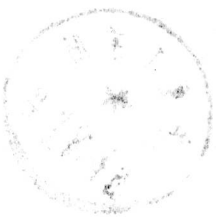
Contents



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Introduction and Overview

This chapter indicates how the book is organized and summarizes the philosophy of presentation. This is accomplished by discussing the term "systems analysis," describing the role which it has played in the acquisition of systems, (particularly defense systems) and showing that it is actually a form of systems planning performed at the decision-making level. The role which President Johnson has directed systems analysis to play in the nondefense area of federal programs is also discussed. Finally, a summary of the key topics of each chapter is presented in order to give an organizational "road map" to the reader.

The field of systems analysis, (sometimes called cost-effectiveness analysis, cost-benefit analysis or cost-utility analysis), as applied to the decision-making process, is relatively new. It has achieved its greatest development in the area of defense systems under the direction of Robert S. McNamara, the eighth Secretary of Defense. However, since the objective of systems analysis is to aid a manager in decision-making, it can be applied beneficially to many other fields when choosing a preferred alternative on some rational basis is the key problem. Application of systems analysis to the nondefense sector of the national government was advanced by President Johnson when he directed * that every department and agency of the government "will set up a very special staff of experts who, using the most modern methods of program analysis, will define the goals of their department for the coming year. And once these goals are established this system will permit us to find the most effective and least costly alternative to achieving American goals." †

Following the presidential announcement, Charles L. Schultze, Director, Bureau of the Budget, made these points about the new approach: ‡

* Presidential Directive, August 25, 1965.

† As discussed in Chapter 4, the President no doubt meant "the most effective alternative at given cost, or the least costly alternative to achieve a given level of effectiveness," but not an unachievable mini-max solution.

‡ *The New York Times*, August 26, 1965.

"It is not designed to make decisions but to enable us to ask the right questions. There would be no computerized decision-making.

"It is designed to make the government work all year long on its future programs instead of crowding all the work into the last few hectic weeks of the year as the budget is being drawn up.

"It is also designed to give, where possible, the cost of a given program over several years ahead instead of just for the immediate budget year."

These management techniques are also being applied to large problems of the state and local governments. For example, California has utilized trained systems analysts from the aerospace industry to cope with problems of transportation, waste management, crime, and smog in a state pilot project.

Much has been written about the so-called management revolution which has taken place in the approach to managing what has been called the world's largest business, the Department of Defense. Many dollars have been expended in this area to develop better management techniques for coping with the difficult problems of decision-making with which the Defense Department is faced. Many of these techniques have a direct carry-over to the problems of optimal resource allocations (i.e., systems planning) in any organization.

WHAT IS SYSTEMS ANALYSIS?

The term "systems analysis" has been used by different practitioners to describe different classes of work. To emphasize the differences, I will describe these classes in exaggerated form. At one end of the work spectrum are the mathematically oriented analysts who wish to apply a set of optimization techniques to highly structured problems. Thus at the extreme, if a decision-maker provides them with a well defined structure to his problem, including the objective he wishes to optimize (e.g., company profit or targets destroyed), the analyst will compose a set of mathematical or logical equations containing a set of relevant variables of interest and boundary condition constraints, and will find some way of determining the mathematically optimum operating point of the system. Such work might be called "the mathematics of systems analysis."

On the other end of the work spectrum (e.g., as exemplified by the systems analysts of the RAND Corporation) are those analysts whose starting point is the unstructured problem of the decision-maker. Their major objective is to build a proper structure to the problem, including uncovering the true goals of the decision-maker. Their emphasis is on what might be called

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