
APPLIED SYSTEMS ANALYSIS

Engineering Planning and Technology Management

Richard de Neufville

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of Technology*

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ABOUT THE AUTHOR

Professor Richard de Neufville is Founding Chairman of the Technology and Policy Program at the Massachusetts Institute of Technology (MIT). This innovative curriculum in systems planning and management received the Sizer Award for the Most Significant Contribution to MIT Education.

Professor de Neufville received his bachelor of science, master of science, and doctorate in civil engineering from MIT.

He has taught Applied Systems Analysis at MIT since 1968, in both the School of Engineering and the School of Management. He has also held visiting appointments in Engineering at the University of California, Berkeley, and the Ecole Centrale de Paris, and in Management at the London Graduate School of Business and the Master's in International Business Program in France. His previous book for McGraw-Hill, *Systems Analysis for Engineers and Managers*, was awarded a NATO Systems Science Prize.

His work in decision analysis and strategic planning is widely recognized for its impact on professional practice. His experimental research won the Alpha Kappa Psi and the Risk and Insurance Awards. Most recently, the Australian Institution of Engineers cited his work on the Second Sydney Airport for Engineering Excellence.

The author of two other textbooks, *Airport Systems Planning* (MIT Press and MacMillan in England) and *Systems Planning and Design* (Prentice-Hall), Professor de Neufville was named as a U.S.-Japan Leadership Fellow in 1989. Previously he was a Guggenheim Fellow and served as a first White House Fellow for President Johnson.

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THE TOPIC

Applied Systems Analysis is the use of rigorous methods to help determine preferred plans and designs for complex, often large-scale systems. It combines knowledge of the available analytic tools, understanding of when each is more appropriate, and skill in applying them to practical problems. It is both mathematical and intuitive, as is all planning and design.

Systems Analysis is a relatively new field. Its development parallels that of the computer, the computational power of which enables us to analyze complex relationships, involving many variables, at reasonable cost. Most of its techniques depend on the use of the computer for practical applications. Applied Systems Analysis may be thought of as the set of computer-based methods essential for the planning of major projects. It is thus central to a modern engineering or business curriculum.

Applied Systems Analysis covers much of the same material as operations research, in particular linear and dynamic programming and decision analysis. The two fields differ substantially in direction, however. Operations research tends to be interested in specific techniques and their mathematical properties. Applied Systems Analysis focuses on the use of the methods.

Systems Analysis includes the topics of engineering economy, but goes far beyond them in depth of concept and scope of coverage. Now that both personal computers and efficient financial calculators are available, there is little need for professionals to spend much time on detailed calculations. It is more appropriate to understand the concepts and their relationship to the range of techniques available to deal with complex problems.

Applied Systems Analysis emphasizes the kinds of real problems to be solved; considers the relevant range of useful techniques, including many besides those of operations research; and concentrates on the guidance they can provide toward improving plans and designs.

Use of Systems Analysis instead of the more traditional set of tools generally leads to substantial improvements in design and reductions in cost. Gains of 30% are not uncommon. These translate into an enormous advantage when one is considering projects worth tens and hundreds of millions of dollars.

SCOPE OF TEXT

The object of this book is to help the student and practitioner learn to apply Systems Analysis successfully and productively. It is addressed to the user, who has to know how to select the techniques appropriate in any situation, to apply them to real problems, and to interpret their results intelligently. It is also addressed to the customer, the person responsible for large projects, who has to know how to evaluate the results and proposals generated by systems analysts. To meet their needs, the text presents the techniques and concepts that have been found to be most important in practice.

The text presents the fundamental topics of optimization and evaluation. Each is treated differently, according to the state of analytical and conceptual progress in the area.

Optimization focuses on linear and dynamic programming as the central methods of interest in practice. Insofar as standard computer programs are available to execute these methods, the emphasis here is on how to formulate problems correctly and efficiently, and on how to translate the mathematical results into improved designs. Procedures that are not used in practice, such as the simplex method, are bypassed so that time can be spent productively on important considerations. The presentation is integrated with the classical techniques of engineering and economics so that students can learn to exploit the range of methods according to their needs.

Evaluation features decision analysis as the principal means to identify optimal strategies in the risky environment that is necessarily part of complex, long-term projects. Indeed, use of this approach is leading to fundamental improvements in the way we plan such developments. The presentation here is unique in the way it integrates decision analysis into the hierarchy of evaluation techniques. Each of these, particularly including engineering economy and cost-benefit analysis, is described in sufficient detail.

The text does not cover two topics sometimes included in systems analysis: dynamic systems and statistics. Dynamic systems are not treated because their applicability to problems of management and design, as distinct from mechanical systems, is minimal. Research into the possibility that large-scale physical systems and organizations can be described with feedback loops and the like is suggestive but still too speculative for actual practice. Classroom experience, on the other hand, indicates that statistical procedures are extremely difficult to integrate effectively with optimization and evaluation: A careful treatment of the methods and issues requires more understanding of probability and causal mechanisms than is generally available.

A major strength of the text, as emphasized by reviewers, is the way it effectively integrates the broad range of methods available to the user. The idea throughout has been to help the user understand the relative strengths and weaknesses of alternative methods, to indicate when they are best used, and to provide guidelines for application.

PRESENTATION

The presentation of the techniques differs substantially from that of competitive texts. It particularly features

Application to real problems, drawn from an extensive range of practical work over the last 20 years.

Synthesis of the methods, ordinarily treated quite distinctly in separate texts, into an integrated framework.

Consideration of multiple objectives, as a realistic feature of the actual nature of planning and management.

The text is easy to use for teaching and learning because it does not require extensive mathematical skills. Because people who need to apply Systems Analysis come from a wide range of backgrounds, every effort has been made to avoid unnecessary mathematical complexity. The idea is to teach, not to impress. Readers should, however, be familiar with

Elementary Calculus, so that they can deal with the classical techniques of optimization.

Vectors and Matrices, the basic means of describing problems to computers.

Elementary Probability, to work with expected values.

They should also have some acquaintance with real-world problems, so that they can appreciate when and why some techniques are better than others.

Making the material easy to learn and to teach has been a leading consideration. Great care has been devoted to defining concepts clearly and consistently, to giving and explaining examples, and to making the text completely self-contained. The language and sentences are also kept as simple and as direct as possible, in recognition that a text may be used as much at one in the morning as at one in the afternoon!

The format uses three special devices to make learning easier. These are

Boxes, self-contained blocks of material inserted in the text, that highlight examples.

Semantic Cautions, indented sections drawing attention to potential ambiguities caused by conflicting definitions used in different disciplines.

Italicizing of definitions where they first appear, to help readers locate and refer to important concepts.

Additionally, references to detailed case studies easily available in the literature are provided where appropriate.

Both conceptually and pedagogically, *Applied Systems Analysis* is a complete rewrite of my previous textbook (*Systems Analysis for Engineers and Managers*, coauthored with Joseph Stafford). It includes many case studies, drawn from a second text (*Systems Planning and Design: Case Studies in Modeling Optimization and Evaluation*, coauthored with David Marks) and two decades of worldwide professional experience. It incorporates recent developments while dropping topics that have proven to be of little use in practice. It offers a wider, more instructive range of problem sets. Finally, it is written to be clear, even on the most difficult points.

The text reflects the current pervasive use of personal computers throughout, in its choice of topics and their use. The material on sensitivity analysis, multi-objective optimization, and system optimization procedure can only be applied to realistic problems when computers are available. Likewise, topics such as the evaluation of cash flows are best done in practice by spreadsheet programs. As a practical matter, however, specific programs have not been incorporated into the text, because of the enormous, ever-changing variety of software available. Experience suggests that instructors will find it easiest to use the programs with which they and the students are familiar. Alternatively, if there is not enough time to go into the mechanics of specific software, the material may be covered completely without computers.

SUGGESTED USE

The material works well for the wide range of users who need a comprehensive introduction to Applied Systems Analysis. It provides in one text the material ordinarily found only in several specialized subjects. Years of classroom experience indicate that introducing students to Systems Analysis in this way, with many examples of real applications, is highly motivational: It encourages students to select the more advanced topics that will be most useful to them.

Juniors and seniors in engineering follow the mathematics easily and are challenged by the references to practice. Entering graduate students who have not previously had Systems Analysis appreciate the way the applications motivate the study of the techniques.

The text is also appropriate for first-year students in management, provided they have had a reasonable grounding in mathematics. It is routinely used in this context both at the Massachusetts Institute of Technology and in the Master's in International Business Program in France.

Experienced professionals appreciate the way the material applies to real problems. Although some may have to brush up analytic skills, many have used the material for self-study and reference. The predecessor text, *Systems Analysis for Engineers and Managers*, was adopted by the Open University in Britain for nationwide educational television. It was also awarded the NATO Systems Science Prize.

At the Massachusetts Institute of Technology we now present the material in two kinds of subjects. In the fall, it is given as a schoolwide elective taken by seniors and graduate students in all fields of engineering. During the spring and summer it is given to professionals entering business school programs.

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PART
1

SYSTEM
OPTIMIZATION