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Reviews

E. S. QUADE (editor), *Analysis for Military Decisions*, Rand McNally and Co., Chicago, Ill., 1964, 390 pages, $10.00

IN ITS work for the United States Air Force, The Rand Corporation has played a leading role both in developing systems analysis and in applying it to making decisions in the face of uncertainty in problems relating to national defense. Those of us who have been engaged in systems analysis since the early 50's will remember the many philosophical discussions, blind alleys, methodology experiments, and frequent 'customer' hostilities that were part of this birth process. But through it all a method has evolved and become an important part of government decision-making processes—CHARLES J. HITCH's *Decision-Making for Defense* [University of California Press, 1965, reviewed in this journal by HUGH J. MISER, **13** (1965), pages 863–869] gives an authoritative summary of the use of systems analysis in the Department of Defense, and on August 25, 1965, President Johnson asked Federal agencies generally to adapt the DOD planning-programming-budgeting system to their operations, a step that promises a wide-spread growth in the use of systems analysis throughout the Federal government. So it is high time now for Rand to issue its memoirs and to explain the philosophy to the broader audience of executives and decision makers who will now come into contact with these methods.

In 1955, and again in 1959, Rand offered an intensive five-day course entitled "An Appreciation of Analysis for Military Decisions" to military officers and to civilians associated with the armed forces. Since it was designed for decision makers and not for systems analysts, the course stressed the philosophy, uses, abuses, and management visibility of systems analysis, rather than the detailed technical skills it used. Thus, this book, which reproduces the material covered in the course, is neither a reference work on systems analysis nor a how-to-do-it book—rather, it is a critical evaluation written from a vantage point, doing for laymen in systems analysis what PROF. GEORGE GAMOW did in a lighter hearted way for laymen in mathematics and physics with his *One, Two, Three, . . . Infinity* and *Biography of Physics*. However, in his review of Hitch's book, Miser correctly referred readers to QUADE's book for an appreciation of the requirements for valid construction of the systems analyses that must be performed in support of a planning-programming-budgeting cycle.

The contributors to this book include: PAUL ARMER, G. H. FISHER, C. J. HITCH, MALCOLM W. HOAG, R. N. MCKEAN, W. H. MECKLING, E. W. PAXSON, R. SCHAMBERG, T. C. SCHELLING, R. D. SPECHT, M. G. WEINER, ALBERT WOHLSTETTER, and the editor, a group well able to subject the field to critical analysis.

Part One, *Orientation*, contains chapters by Quade and Hitch, followed by a case history relating to selection of air bases, written by Quade, but based on a major systems analysis undertaken at Rand in the early 1950's. The point is made right from the beginning that true systems analysis aims at relating *all* the vital factors of a problem and does not, per se, emphasize mathematical optimization techniques in an oversimplified model of the situation: "A good deal of the earlier work tended to emphasize mathematical models and optimization techniques. Honors went to practitioners who used or improved mathematical techniques like linear programming or queuing theory and found new applications for them. These people were usually associated with decision makers who knew what their objectives were and how to compute their costs, largely in terms of some single, clear-cut criterion. On the other hand, systems analysis—while it does make use of some of the same mathematics—is associated with that class of problems where the difficulty lies in deciding what ought to be done—not simply how to do it—and honors go to the people who have the ability or good fortune simply to find out what the problem is."

In discussing USAF force-mix problems in Chapter 2, Hitch comments on the breadth of system studies. He cites the need for them to incorporate explicit objectives, total costs, incremental costs, defined criteria, time-phasing, and explicit treatments of both uncertainty and enemy actions. In a critical appraisal of the alternative to doing systems analyses, namely, relying on intuition, he cites cases both where intuition has been superb, and where it has gone astray. He notes that, while we trust a man's intuition in a field in which he is expert, in modern complex military problems there is no one man who is expert in all areas. Hence, systems analysis should be looked upon, not as the antithesis of judgment, but as the framework which permits the judgment of experts in many fields to be utilized.

The air-base study, summarized by Quade in Chapter 3, exemplifies a good many of the factors to be discussed in the remainder of the book. It points out the need for a two-sided war-game analysis to estimate the vulnerability of air bases under various assumptions as to who begins the war, the methods of attack, etc. An important point in the analysis is that the objective of such a study is not always to locate an optimum policy. Rather, a policy favorable in view of any of a spectrum of enemy actions may be preferred.

Part Two, *Elements and Methods*, contains five chapters covering model building, selection of criteria, relevance of costs, design and formulation of systems studies, and systems-analysis methods. Specht makes the point that the same real-world item may be modeled in various ways: He humorously refers to a hypothetical Martian flying saucer—while it is being built on Mars, its physical properties are represented in a production and inventory model; enroute to the earth, it is a point mass in a trajectory model; when approaching the earth, it is treated as a radar cross section in a detection model; and so on. "One model's relevant is another's immaterial."

The criteria chapter (5) by McKean includes an excellent discussion of criteria errors, such as ignoring uncertainty. If a system is selected which 'on the average' destroys a target complex for least cost but which fails miserably one time in five, the criterion may prove to have been a bad basis for choice.

Hoag's cost chapter (6) centers about the concepts of *real cost*, the value of the alternative objectives that are sacrificed when a given system is selected. Among the cost aspects considered is the question "which costs are pertinent in a given study?" In costing a ballistic missile force, do we include warhead costs? Criteria also are important. The example is given of arriving at two optimal sizes for an airport parking lot, one size of lot and pricing policy from the criterion of maximizing net parking revenues, and another size and pricing policy from the criterion of maximizing net airline operating revenues as a whole.

Wohlstetter and Quade in Chapters 7 and 8 discuss many of the uncertainties and problems met in formulating a valid systems study. In view of these difficulties, the fact that the models and results of the analysis can seldom be tested (you can't have a war to test a war game), and the usual case that the analysis must be made against a time schedule, Quade concludes that systems analysis is more closely related to engineering than to science. He believes it is one point in a spectrum: "A glass engineer successfully plans the production of certain kinds of optical glass on the basis of chemical knowledge; a lens-designing engineer designs camera lenses on the basis of the knowledge of optics, the techniques of lens manufacture, and the general capabilities of the glass engineer; a camera designer designs a camera on the basis of his knowledge of many things, including what the lens designer can do; the aeronautical engineer designs a reconnaisance plane using, among other things, his knowledge of what he can expect from the camera designer; the systems analyst designs a reconnaissance system knowing what he can expect from the plane designer."

Portions of the third major part of the book, *Special Aspects*, are still methodological and logically belong to Part Two. But this misplacing is not important, for these chapters each have a powerful contribution to make, and it is only important that they *are* included in the book.

Chapter 9 by Schamberg deals with a number of technological performance parameters and how scaling laws, etc., may be used in trade-off studies. It makes the important distinction that a performance parameter (like speed and altitude) is a description of a hardware capability and *not* a measure of its intrinsic worth (military or economic). Chapter 10 by Schelling considers some of the problems of trying to take enemy action into account in the analysis. Since the enemy will not necessarily "do his worst," this assumption can mislead the analysis. Thus, one of the objectives of the selected system might be to make the enemy react to our choices in ways that we desire him to; for example, we might make him spend resources to defend his bomber bases.

The discussion of gaming methods and simulation in Chapter 11 by Weiner still speaks of large bookkeeping games as being so complex "they exceed any reasonable machine capacity," a remark that seems a bit dated when modern computer capabilities are compared with those of the 1950's. But in all, the chapter is functionally written and interesting.

Chapter 12 on the relation between systems analysis and development decisions contains several valuable observations. Noting that costs are often underestimated by factors of 2 to 10, while performance is seldom missed by more than 25 per cent, Meckling says that "performance estimates tend to be more accurate simply be-

cause money and time, the other two variables, are sacrificed to meet original performance requirements." The second point is that studies to select future vehicles that are not yet developed should not necessarily be aimed at selecting an end-product force. Rather, if uncertainties cause the study to show no clear-cut advantage, the best conclusion might be to spend limited sums on further development to produce more information about costs and performance, and then to rerun the analysis, with the final choice being made at a later date.

The chapters on mathematical models (13, Quade), use of computers (14, Armer), and costing methodology (15, Fisher), are well written and explain the role of these techniques in the total systems study. Quade's Chapter 16 on pitfalls contains worthy examples, and deserves to be read periodically by the practicing analyst who desires to avoid them.

Part Four, *Summary*, contains a single chapter, *Recapitulation*, by Quade. It is written around two lists: *Precepts* and *Questions*. The first is a check list of the principles that have been enunciated throughout the book; the second is a list of those questions which the recipient of a systems study might ask to clarify his thinking or to uncover weaknesses in it. The analyst who applies these lists to his next systems study before releasing its results will probably save himself embarrassment.

The *Appendixes* contain two case histories that illustrate some of the concepts presented in the book. The analysis of the lunar base problem by Paxson shows how a valuable organization of a complex problem may result from systems analysis even though not enough data are available at the time for quantitative conclusions.

The real impact of the book, however, is the guidepost that it establishes for the development of systems analyses in other areas of national decision. It is inevitable that as communication, data-processing, and educational sophistication in management grow, we shall cease to settle our national problems on the basis of who has the strongest lobby. Some national problems in the past have obviously been related to each other, and yet have been resolved *in vacuo* by yielding to the strongest pressure group, without any relation to over-all national objectives. As examples, we have only to name the controversy between farm surpluses, grain for Russia, and national defense; or, the War on Poverty, urban renewal, educational plans, and the urban transportation and highway problems In all of these cases the previous compartmented, intuitive, political approaches must some day give way to the explicit, cost-effectiveness, programming, and budgeting treatment described in this book. President Johnson's recent request for other Federal agencies to adopt this approach to planning should hasten its effective use in connection with many important national policy issues.

Just the identification of national objectives (which systems analysis forces us to enunciate) with respect to 'one world' and UN activities, as well as international programs of food distribution, commerce, development of backward nations, and population control, will be a major step forward. On the other hand, in the national space program, large trade-off models for total space programs have already been built under NASA contracts, and applied to decision problems; these models have, in fact, incorporated many of the precepts discussed in this book.

As a nontechnical primer of what has been learned in fifteen years of systems analysis at Rand, this book is a milestone in clearly explaining the systems-analysis

art to the layman. However, on the negative side, it seems a bit parochial (since it includes almost entirely references developed at Rand or by former Rand analysts) —some chapters could definitely have been strengthened and broadened by including other experience. And there are some typographical blemishes.

Too, it might have been desirable, if at the end an attempt had been made to devise a how-to-do-it general systems-analysis flow chart. Such a chart, together with the addition of problems and exercises, would have made the book usable as a text for part of a university course in systems analysis for engineers. In this role it would complement the excessive emphasis on mathematical optimization methods which are now the center of such systems courses.

The book is recommended to the decision-maker, to the student, and to the engineering specialist who desires to understand what systems analysis is. It is also recommended to the practicing analyst as a touchstone to refresh his memory on the fundamental mistakes and pitfalls to be avoided in his analyses.

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JOHN C. G. BOOT, *Quadratic Programming: Algorithms—Anomalies—Applications*, Rand McNally & Company, Chicago, Illinois, 1964, 231 pages, $6.50

AT THIS stage in the development of operations research, it is probably unnecessary to explain that quadratic programming is the problem of maximizing a concave quadratic function subject to linear inequality constraints. It is a topic nearly as old as linear programming and continues to attract the attention of many investigators.

This book is primarily based on the author's researches in quadratic programming, five of which have already appeared in the periodical literature. With one exception—a joint paper in which an application of quadratic programming is reported—the principal contribution in these studies is the treatment of the influence of anomalies (such as trivial constraints, dependency, and degeneracy) upon certain algorithms.

Taken by chapters, the contents of the book are as follows. In Chapter 1, the quadratic programming problem is introduced through some standard applications (portfolio selection, constrained least squares regression, and resource allocation) and then stated formally. The quadratic objective functions here are always assumed to be concave and, in all but the last chapter, strictly concave. The notation used in the book is consistent and very carefully explained.

Chapter 2 is devoted to some mathematical preliminaries. It is assumed that the reader is already familiar with the rudiments of matrix algebra; otherwise, the book is self-contained. It is perhaps worth noting, however that this is no book for the reader who is disturbed by matrix-vector manipulations or the Greek alphabet. Both are used extensively. This chapter and three others have appendixes where matters which might unduly impede the reader's progress are handled.

Trivial constraints are the subject of Chapter 3. A trivial constraint is one

whose removal from the system of linear inequalities does not alter the feasible region. A procedure for the elimination of trivial constraints is described; it suggests that for theoretical purposes the side conditions in the programming problem may be regarded as free of trivial constraints.

Chapter 4 is concerned with the simplex method and duality theorem of linear programming. While the treatment is generally quite good, the reviewer was somewhat disheartened by the opening sentence, which reads: "Linear programming is a very special case of quadratic programming." This is, of course, true in the case where the quadratic part of the objective function vanishes identically—which, incidentally, cannot happen when the function is strictly concave. To the reviewer, it makes good mathematical sense and even better historical sense to say that quadratic programming is an *extension* of linear programming. One of the amusing parts of Chapter 4 is an appendix in which it is shown how a procedure called "the cosine algorithm" fails to work in dimensions higher than two.

The detrimental role of degeneracy and dependency in the Theil-Van de Panne approach is explained in Chapter 5. This procedure represents an effort to throw the quadratic programming problem back on the classical problem of maximizing a quadratic function of a vector variable constrained by a system of linear *equations*; this is the type of problem to which the familiar method of Lagrange multipliers is applicable.

In Chapter 6, the Lagrangian and Houthakker capacity methods are presented. In these procedures, an extra, parametric, side condition is added to the other constraints. It is shown how the Houthakker method can break down in the presence of multiple degeneracy.

An application of quadratic programming is discussed at length in Chapter 7. This application involves the use of surplus milk in the Netherlands, and entails a parametric 'policy constraint' thereby making capacity methods particularly appropriate for solving it.

The sensitivity analysis of infinitesimal and persistent changes in the data of a quadratic programming problem is the topic of Chapter 8. Readers of this journal may recall the author's paper on this subject in Vol. 11 (1963), pp. 771–786.

The ninth and last chapter deals with quadratic programs in which the assumption of *strict* concavity is relaxed. Greatest attention is given to an algorithm of Dantzig that was later discovered independently by Van de Panne and reported in a more complete and rigorous fashion by Van de Panne and Whinston. Other procedures due to Barankin and Dorfman, Frank and Wolfe, and Wolfe are also briefly sketched. The author states that of all these algorithms, Dantzig's appears to be the most efficient.

The book ends with an adequate index and a bibliography listing most of the important literature up to 1963.

What is done in this book is done well. The exposition is clear, well illustrated with examples, and relatively free of errors. Yet it must be pointed out that what is *not* done in this book could easily fill another volume. Several well-known algorithms are omitted (foremost among which is Beale's). Also absent are discussions of historical details, the duality theory of quadratic programming, related problems such as the constrained maximization of nonconcave quadratic functions and integer quadratic programming, a broad discussion of applications, and finally

comparative studies based on computational experience and a list of available computer codes. To cover this material as thoroughly as Boot has covered his will be a difficult task.

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RICHARD I. LEVIN and C. A. KIRKPATRICK, *Quantitative Approaches to Management*, McGraw-Hill Book Company, New York, N. Y., 1965, 379 pages, $8.50

THE authors have prepared this text to fill a need for an approach to quantitative methods in management that is clear and understandable without mathematical background, yet sound and respectable. The book is not intended to appeal to the mathematician or scientist interested in the management field. Rather, it is intended to give college and business people without mathematical background an understanding of some of the quantitative methods that can be used in management. The authors succeed quite well in discussing several OR techniques while studiously avoiding the calculus and cautiously using simplified notation. However, they find that they are required to introduce elementary concepts of probability, statistics, vectors, determinants, and matrix algebra.

The text is concerned not only with describing the OR techniques, but also with formulating and solving numerical problems. Anyone who is concerned with the problems of management but is unaware of operations research could improve his understanding of quantitative methods in management by reading this book. However, no one should be deluded into believing that knowledge of this text alone would permit him to practice operations research.

The subjects covered in the book include the scientific method, breakeven analysis, probability, statistics, inventory, vectors, matrix algebra, linear programming, game theory, Markov analysis, and queuing.

- The introduction deals with the scientific method and the approach of operations research. If we presume a reader who does not have much background in mathematics, engineering, or science, and for whom the subjects of the introduction will be new, the introduction is too brief and does not deal sufficiently with the concept of the scientific model and the relation between the abstract world of the model and the real world of the problem. However, interest in the subject is created by several good examples.
- The chapter on breakeven analysis covers the subject in an elementary way, with some tedious arithmetic.
- The chapters on probability and statistics give a nice presentation of the subject numerically in capsule form. The treatment of Bayes's theorem is especially well done. The examples involving expected value are also well presented.
- The chapter on inventory takes the reader through some elementary problems involving economic order quantity, again without using calculus.
- The chapters on vectors, determinants, and matrix algebra also give a nice numerical presentation of the subject, including independence of vectors and some examples of expressing and solving simultaneous equations.
- The chapters on linear programming are very clear and the examples are well

done. The simplex method is explained numerically, including an interpretation of the simplex tableau. In addition, the use of artificial variables is demonstrated. No reference is made to the dual problem or its economic significance. A transportation problem is solved by the inefficient simplex method, although the stepping-stone method is mentioned.

● The chapter on games is one of the best in the book. It describes very clearly, by numerical example, pure and mixed strategies, saddle points, dominance, and graphic, algebraic, and linear programming solutions of rectangular games. However, its arguments on management uses of the theory of games is weak, and no other treatment of competitive strategies is given except by game theory.

● The chapter on Markov analysis is also very good. The development of transition probabilities and equilibrium conditions is presented clearly by numerical examples.

● The chapter on queuing presents a Monte Carlo simulation of a queuing problem in clear detail, but contains nothing about queuing theory.

There is no treatment of any other OR method such as replacement, maintenance, sequencing, routing, critical path, network flow, or dynamic programming. In general, the book offers a very light and inviting treatment of operations research, and, hopefully, may gain some converts to the study of our science.

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