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Reviews

STUART E. DREYFUS, *Dynamic Programming and the Calculus of Variations*, Academic Press, New York, N.Y., 1965, 270 pages, $9.00

BEFORE proceeding to a review of this book, I must give two possible interpretations for the term *dynamic programming*:

(1) Dynamic programming describes the subject matter of the mathematical theory of multistage decision processes. (This first interpretation is due to RICHARD BELLMAN, who coined the term.)

(2) Dynamic programming is a particular approach to (1), which is based on three main ingredients: the principle of optimality, the optimal value function, and the (Bellman) functional equation. (With this interpretation, dynamic programming can be considered as a systematic presentation, coordination, and generalization of the ideas of MASSÉ and CARATHÉODORY.)

In DREYFUS' book and in this review, the term dynamic programming should be understood as having the second of these interpretations.

The book has seven chapters. Since Chapter I, *Discrete Dynamic Programming*, and Chapter VII, *Stochastic and Adaptive Optimization Problems*, are very well done but outside the central purpose of the book, this review will be devoted entirely to Chapters II through VI.

In Chapter II, *The Classical Variation Theory*, the author gives a very clear survey of the results of the classical calculus of variations.

In Chapter III, *The Simplest Problem*, the aim of the author is to derive the results of the classical calculus of variations with the help of dynamic programming. This derivation, similar to the one given by Carathéodory in the fifth chapter of the book *Die Differential-und Integralgleichungen der Mechanik und Physik*, edited by FRANK AND VON MISES (Braunschweig, 1925), proceeds from the following assumption: the Hamilton-Jacobi partial differential equation associated with the variational problem has a solution, or equivalently, using dynamic programming terminology, the optimal value function exists and is smooth enough. This derivation illuminates the geometric aspects of the calculus of variations and is a useful mnemonic device to check the correctness of final formulas, but it cannot be considered an alternative approach to the calculus of variations. On this point the reviewer respects the author's opinion, but does not share his optimism when he states in the introduction: "Indeed, a completely rigorous presentation would necessarily be at odds with the primary goal of intuitive clarity. The question is left open as to whether the dynamic programming approach to problems of the calculus of variations, if pursued for several hundred years (as has been the classical theory) and if rendered completely rigorous, might yield results that are either slightly sharper or slightly weaker than those of the classical theory. At this moment of its infancy, it is fairly safe to say that the dynamic programming results, at a rather subtle level, are weaker."

Chapter IV, *The Problem of Mayer*, is a technical extension of Chapter III.

Chapter V, *Inequality Constraints*, considers the type of problems that have been at the origin of the theory of optimal control. In this chapter the author applies again the formal methods of dynamic programming and states Pontryagin's maximum principle. Whereas in Chapter III the optimal value function is, in general, smooth enough to justify the application of these formal methods (a proof of that fact is found in the theory of the Hamilton-Jacobi partial differential equation), this is not the case for the problems treated in this chapter. On page 171 the author states: "The above result was derived by Valentine in the 1930's by modifying classical arguments and recently was rederived by the eminent Russian mathematician L. S. Pontryagin who termed it 'the Maximum Principle.' " Such a remark, unfortunately common, is very misleading. L. D. BERKOVITZ has shown that some fairly general form of Pontryagin's maximum principle can be obtained from the following three elements: (1) the classical calculus of variations (with the treatise of BLISS as a standard); (2) VALENTINE's dissertation; and (3) the multiplier rule for the abnormal problem of MAYER, a result due to McSHANE. The fundamental paper of L. D. Berkovitz is often misunderstood as based on elements (1) and (2) only. This is unfortunate, since, of these three elements, McShane's result is the *only one* that is strictly necessary, as Pontryagin and his associates have shown in their proof of the maximum principle, which is based on a very useful device introduced by McShane: the consideration of some convex variations and the separation properties of some convex sets. The maximum principle is the most important necessary condition in the theory of optimal control: it characterizes the separation of some convex sets. There is no hope of ever deriving this result with any method that does not refer, directly or indirectly, to the concept of convex sets and their separation.

Chapter VI, *Problems with Special Linear Structures*, presents a real challenge to the devoted dynamic programmer: "The troublesome types of problems that we shall investigate have what seem to be particularly simple forms and appear frequently in the literature. While it is certainly advisable to study simplified problems before attacking the complicated situations found in nature, the properties of the simplified problems that are treated in this chapter turn out to be atypical of the properties of most practical problems. For this reason, we feel that these special types of problems have been receiving undue emphasis and that a short chapter near the end of this book is their appropriate habitat" (page 190). The only trouble with these simple problems is that they put in full view the shortcomings of dynamic programming that are so easily hidden, but still present, in more complex problems. The interested reader should compare Chapter VI with the fundamental papers: R. E. BELLMAN, I. GLICKSBERG, and O. A. GROSS, "On the 'Bang Bang' Control Problem," *Quart. Appl. Math.* **14**(1956), pp. 11–18; and J. P. LA SALLE, "Time Optimal Control Systems," *Proc. Natl. Acad. Sci.* **45**(1959), pp. 573–577.

This book is well organized and clearly written, but the topics of Chapters I and VII are the ideal ground to apply the methods of dynamic programming. I hope that the author will expand these two chapters into a full book in the near future.

HUBERT HALKIN
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ROBERT G. BUSACKER and THOMAS L. SAATY, *Finite Graphs and Networks: An Introduction with Applications*, McGraw-Hill Book Co., New York, N.Y., 1965, 308 pages, $11.50

THIS book is another addition to the rapidly increasing number of books on graph theory, a subject which up to ten years ago was virtually represented by only one book, the now classic *Theorie der Graphen* of KONIG. Like most of the books on this branch of mathematics, it aims to be a general work, giving a broad account of the subject as a whole, rather than dealing with any very specialized topics. This aim is reflected in the subtitle *An Introduction with Applications,* and the book itself is in two parts, *Basic Theory* and *Applications.*

Part I, *Basic Theory,* gives a good introduction to most of the fundamental theory required to understand the results of 'pure' graph theory, and of its various applications; in particular it provides the background necessary for the appreciation of Part II. The first two chapters define and discuss the concepts, terminology, and notation relating to undirected and directed graphs respectively. Chapter 3 discusses various problems of partitions and distances in graphs, and Chapter 4 is concerned with planarity of graphs (including a proof of the famous theorem of Kuratowski) and with various problems associated with colorings. The study of the various matrices associated with a graph and their properties is undertaken in the final chapter of Part I.

The theory of graphs is becoming increasingly familiar and increasingly useful as a mathematical tool not only in mathematics itself, but also (perhaps more so) in economics, operations research, and sociology, as well as in many other diverse fields of study. Part II of this book gives an up-to-date introduction to all the more common applications. Of special relevance to those interested in operations research is the first section of Chapter 6, which deals with applications in economics and logistics, including, for example, a graph theoretical criterion for the existence of the inverse of the matrix of an open input-output model. Linear programming is touched upon, and then there follows a full description of PERT, with an illustrative example.

The rest of the long Chapter 6 (it occupies nearly half the book) deals with various other applications, which can be briefly listed as follows: combinatorial problems, puzzles and games, matchings, engineering applications, physical sciences applications, human sciences, and others. The important topic of flows in networks is (rightly) given a chapter to itself—the final chapter of the book.

The standard of the various sections of the book is very good, and uniform for the most part. The section on combinatorial problems, culminating in the statement of Pòlya's theorem, seems rather too short to do justice to this important branch of the subject, but this is a minor point. Each chapter has a comprehensive list of references.

This book provides an excellent introduction to graph theory for anyone with some mathematical background but without previous knowledge of the subject, and even those already familiar with it may well find much in this book that is new to them.

RONALD C. READ
University of the West Indies

V. E. BENES, *Mathematical Theory of Connecting Networks and Telephone Traffic*, Academic Press, New York, N. Y., 1965, 333 pages. $12.00

THIS book is a collection of eight reasonably independent articles. Some of the material was originally presented in the *Bell System Technical Journal*.

Chapters 2, 3, and 4 present a static analysis of systems that considers only the nature of the set of states of the system. They develop the concepts of rearrangeability, nonblocking in the wide sense, and nonblocking in the strict sense. In the first case, any pattern of calls may be connected, although the connection of a new call in any given situation may require that some existing calls be reconnected using another circuit. In nonblocking networks a new call can always be connected without disturbing existing calls. The two cases distinguish between achieving this property by selecting control rules or by providing sufficient connecting circuits. The discussion focuses attention on several particular classes of switching networks and some questions of optimal design.

The next two chapters consider some statistical questions in traffic measurement in the context of classical parallel-channel queuing models. The first develops sufficient statistics for estimating the parameters of an infinite-channel model, and the second derives the covariance of the number of busy channels.

The final two chapters consider models of system behavior. The first develops the analogy between the behavior of a traffic system and a thermodynamic model, based on the postulate of equilibrium-maximizing system entropy for a given value of traffic. The final chapter deals with a Markov model with call-arrival rate λ and termination rate I, with a set of parameters $\{r_{xy}\}$ giving the probability that a call occurring when the system is in state x leads to a change to state y. It develops the solution for steady-state probabilities in terms of sequences of transitions leading from one state to another. The development of the probability of being in state x as a power series in λ for small λ is particularly interesting.

The emphasis of the book is on combinatoric approaches to the study of traffic networks; statistical and optimization discussions round out the author's concept of the most important elements of a theory of system design. Admittedly, this work is but a start in the development of such a theory. Thus, although the book can be highly recommended to telephone engineers for general education, no one should read it expecting to find his design problems reduced to feasible computational solutions.

Although the importance of this work is not confined to telephone engineering, results from the study of telephone networks will not be as useful in general operations research as the previous queuing theory developments from this field. The reason is that, at least as far as the switching network questions are concerned, telephone systems represent very special types of elementary queuing networks.

From the standpoint of general networks of queues, a call requires a single service, since, from the moment a connection is complete until it terminates, a fixed set of circuits is assigned to it. The interesting extension gained from considering connecting networks in place of previous trunk models is that, instead of requiring a single server, a call requires any one of a number of different groups of specialized servers. More general processing systems permit partial processing followed by temporary delays, and the groups of servers used in this sequential process usually differ at the various stages. Thus, the work in this book must be considered as suggestive of possible directions for general network queuing theory.

For those interested in the development of basic theory, this book's stress on combinatorics deserves careful study.

RICHARD V. EVANS
Case Institute of Technology

ALBERT BATTERSBY, *Network Analysis for Planning and Scheduling*, St. Martin's Press Inc., New York, N.Y., 1964, 220 pages, $8.50

WHEN this book was first published in the United Kingdom, there was literally nothing else available on CPM in textbook form. It has since been followed by a host of others on this side of the Atlantic, but only a few are any improvement. This book is the first in a series in the field of management studies and is intended as a comprehensive source book both for students pursuing formal courses and for executives in industry who wish to keep up to date.

- Chapter 1 outlines briefly the origins of CPM and PERT and the scope of the book. CPM and PERT are considered as variations of the basic technique of network analysis, an approach that might well be copied.
- Chapter 2 shows how arrow diagrams are compiled.
- Chapter 3 defines critical paths and shows how they are calculated by the PERT (that is, the intuitive, or event-time) method.
- Chapter 4 reviews the now obsolete matrix method of calculation, time-scaled networks, and ROY's method of potentials; the latter exposition, though brief, is substantially clearer than Roy's original presentation.
- Chapter 5 discusses time-cost trade-offs, using a quite ingenious book-publishing example, doubtless involving the present volume.
- Chapter 6 treats of resource allocation in network models, but the planning format used in the examples is somewhat difficult to follow and contains a minor error.
- Chapter 7 deals with uncertain durations and PERT, including a brief but lucid elementary treatment of range, variance, the 'normal' distribution, and probability calculations of PERT.
- Chapter 8 contains a treatment of network analysis and management, including descriptions of network size and drawing time for some selected projects. This chapter leans heavily on the PERT and PERT/cost literature.
- Chapter 9 describes a number of practical applications, mainly in the United Kingdom.
- Chapter 10 concerns future developments. Outlined are EISNER's 'decision box' treatment of research networks, the Reliability Maturity Index of

MALCOLM, storage costs, pay events, credit activities, positive and negative payments, present values of network activities, and similar cost questions. In this chapter BATTERSBY also reproduces his fictitious network analysis for the 'Great Train Robbery,' and concludes with a network for the preparation of sweet-and-sour pork!

- The book concludes with appendixes dealing with the mathematical basis of the PERT statistics, and a glossary of symbols and conventions, a number of them foreign to North American practice. There is also a brief bibliography and solutions to the many exercises which appear at the end of each chapter.

In general, Battersby's book is excellent, though perhaps somewhat behind current North American practice, particularly with respect to computer use. The book deliberately avoids any more mention of computers than is absolutely necessary, which was perhaps consistent with 1964 British practice but is scarcely correct here and now. Despite the generality of the title, the book does not deal particularly well with the PERT event-oriented technique.

Some of the examples are a bit obscure, e.g., Ex. 2.4 on p. 29. The use of the widest possible angles in drawing networks, as suggested on p. 23, Fig. 2–17, produces untidy, hard-to-follow diagrams, particularly as complexity increases. The illustration facing p. 137 uses a much-to-be-preferred technique. The 'lead and lag' concept for overlapping activities is interesting, but it can be misleading and even inaccurate, as Battersby himself suggests.

There are a few trifling errors: On p. 75, Table 6.1, under 'New TF' the floats for activities (2, 8) and (3, 5) have become exchanged; the solution to Exercise 3–7 shows the earliest event time as $3\frac{2}{3}$ rather than $13\frac{2}{3}$; and dummy (2, 3) in Fig. S.17(*a*) is not shown as a dummy.

Battersby, like many others, sticks to strict $i < j$ node numbers, though this is not necessary for any computer program really worth using and never for manual calculation. This convention is particularly tedious where network changes are to be made.

The practicality of Battersby's approach is illustrated by his own remark on p. 113: "Network analysis is a capital investment of thought, which pays its dividend in the form of easier control, avoidance of improvisation, and better utilization of resources."

This brief and clear book ranks with the top four or five of the dozen or so books that deal with CPM as distinct from PERT. It is what it says it is, an introductory text for someone anxious to learn about CPM techniques.

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ARTHUR S. GOLDBERGER, *Econometric Theory*, John Wiley and Sons, New York, N.Y., 1964, 411 pages, $10.95

ECONOMETRIC theory developed as an attempt to establish economic theory on a probabilistic foundation. Economic models, in their econometric or probabilistic setting, would be systems of functional relations in which observed 'independent' variables and unobserved 'disturbances' determine the observed 'dependent' variables. Building econometric models, therefore, consists of specifications about (i) the process by which certain observed independent variables are generated, (ii) the process by which unobserved disturbances are generated, and (iii) the relations connecting them to the observed dependent variables. This book is concerned with the more technical aspects of econometry, namely, the methods of estimating and testing relations among economic variables.

Chapters 2 and 3 furnish a compact review of certain essential results in matrix algebra and the calculus of random variables. The first half of Chapter 3 (sections 1–5) does not appear to serve an essential role; the latter half (sections 6–8) could have been improved in content if the author had elaborated the notions of convergence more rigorously and thoroughly.

Chapters 4 and 5, concerned with the classical linear-regression models with nonrandom 'independent' variables, are followed by Chapter 6 where the regressor variables are allowed to be stochastic. Sections 4–7 of Chapter 4 present an excellent account of the problems and methods of statistical inference in linear regression models; they are followed by a brief account of the problems of multicollinearity and of the determination of the 'explanatory contribution' of individual regressors. The use of extraneous information (section 6) and the treatment of qualitative and limited dependent variables (section 5) are the major attractions of Chapter 5. Chapter 6 provides, among other things, a good account of autoregressive equations and of the extent to which one may relax the assumptions concerning the regressors and disturbances without losing the consistency property of the classical least-squares estimators.

The first six chapters do not constitute the main theme of the work, which is to develop "techniques of statistical inference . . . appropriate in economics." The reader who skips section 1 of Chapter 1 will easily convince himself that the treatment in the first six chapters has little to do with *economic* variables. Indeed, the material presented in these chapters could indifferently be described as 'principles and methods of multivariate analysis and inference,' a well-established branch of statistics in which there are at least three good textbooks.

The operations researcher is *necessarily* well acquainted with the principles and methods of multivariate regression. Also, the operations researcher—especially one working with large complexes—is in need of a *theory* and a body of *tools* specifically for the analyses of interconnected systems and the derivation of policy implications. This endeavor is often described as system identification and system measurement. Roughly two decades ago, the founders of econometry had precisely this in mind. It appears that, with the advance of time, emphasis has been shifting to the purely technical aspects that may well be relegated to the professional statistician. How to frame a model such that the constituent relations may be identified and their statistical or empirical counterparts may possess certain desired properties—these are the lessons the operations researcher would like to learn from econometry. It is strange, however, that a noted contributor to the art and science of this subject does not go into 'philosophical' issues that seem to be of immediate interest to those who would like to extend the use of econometry.

This is further evidenced in the size, content, and organization of Chapter 7, which treats the problem of simultaneous (linear) relations. This last chapter, the true core of econometry, provides an excellent account of the principal problem of econometry, namely, the identification and estimation of structural relations under specifications about the random terms. Here, again, the emphasis is on the specific statistical techniques; the formulation and interpretation of econometric models—that which is of interest to the 'uninitiated'—is treated in a very brief section at the end of the book. The interested operations researcher must supplement the material (or, perhaps, begin) with such works as KARL FOX's *Econometric Analysis For Public Policy* and HENRI THEIL's *Economic Forecasts and Policy*.

Specification of the disturbances or 'errors' is not *merely* a statistical issue that has to be settled in order to have valid methods of estimation and inference; one cannot afford to be sloppy in the matter of such specifications. But this is also why one would expect some illustrative examples that throw light on the kinds of reasoning that lead to some specification of the errors. In a book written in 1964, this seems to be a serious gap from the viewpoint of the practical user or customer of econometry.

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DANIEL TEICHROEW, *An Introduction to Management Science: Deterministic Models*, John Wiley & Sons, Inc., New York, N.Y., 1964, 713 pages, $10.95

THIS textbook introduces students of business administration to the use of mathematical methods in business problems, particularly (but not exclusively) those methods which can be classified as operations-research techniques. The need for such a textbook derives from the evolution of highly specialized mathematics curricula in most departments of mathematics. If the student of business administration were to turn to the typical mathematics department curriculum for introductions to the topics covered in Teichroew's one-year course textbook, he would have to take many years of mathematics courses, and in the process acquire a great deal of training in techniques of rigorous analysis, proving of theorems, etc., which would have very little bearing on training him to utilize elementary quantitative methods in business problems effectively.

A balance between mathematical formalism and business applications has been attempted, and "approximately half of the contents is formal mathematics and half is application." Teichroew has obviously made every attempt to allow for an important pedagogical fact of life, namely, that business administration students possess widely varying mathematical backgrounds. He provides detailed explanations of every major topic presented.

The range of mathematical topics presented includes: series; polynomials, exponents, and logarithms; differential and integral calculus; functions of two and many variables; quadratic forms; matrices; linear systems; linear programming; and dynamic programming. The range of business applications presented includes: interest calculations; introduction to modelling; marginal analysis; investment; growth and advertising; product mix; personnel assignment; transportation; and production and employment scheduling.

Another worthwhile feature of this textbook is that the exercises and examples are based, for the most part, on problems to be found in the business, economic, and operations-research literature. The experienced instructor will recognize the great efficiency that results from having available a ready source of context-oriented examples for discussion and/or assignment. Also important is the feature that the textbook has been structured and organized to permit the instructor to make use of a great deal of flexibility in the choice and order of the topics he may wish to cover, including shortening of the course to one semester.

This book is competently and interestingly written. It serves a very important need in a pedagogical area that has experienced a severe shortage of instructional material.

DAVID S. STOLLER
The Rand Corporation

CHARLES H. KEPNER and BENJAMIN B. TREGOE, *The Rational Manager*, McGraw-Hill Book Company, New York, N.Y., 1965, 275 pages, $5.95

THIS book is especially rewarding to the careful reader. At first glance it looks like just another of those works whose message is, "It is obviously good to make problem solving and decision making explicit rather than intuitive. Here is a rather conventional conceptual structure for doing this which all right-minded persons will want to use." It is such a book, but it is more. KEPNER AND TREGOE write with clarity, use well developed examples from actual management situations, and have a fine appreciation for the possibilities and difficulties of communicating their ideas to managers.

The manager who takes the time to go through the book (or attend one of the training programs on which it is based) may find himself becoming something of a scientist. He may learn a good deal about the raising of testable hypotheses and their testing, without getting even slightly involved in terminology. The operations researcher may find here some hypotheses of his own about how to bring science to managers. Indeed the book may be viewed as a basic introduction to, or preparation for, OR. The manager who had made some of these ideas his own would be a sitting duck for an OR man with even a little missionary zeal.

At a different level the book may bring to mind some nagging questions. Why do we so often seem to say, "Intuition is bad, explicitness is good," when the really experienced in any field operate in a largely intuitive manner? Should not one ultimately aim at developing intuition rather than simply supposing it to be ineffective?

WILLIAM T. MORRIS
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LEE J. CRONBACH and GOLDINE C. GLESER, *Psychological Tests and Personnel Decisions, Second Edition*, University of Illinois Press, Urbana, Illinois, 1965, 359 pages, $7.95

THE AUTHORS of this book have prepared an extensive treatment of psychological testing through the use of the statistical-decision and utility-theory approach for persons who are seriously involved with the philosophy, techniques, or uses of testing outcomes as decision-aiding information. The problem confronting the personnel decision maker is not simply that of developing a testing procedure which leads to an applicant's selection or rejection; rather, he is interested in developing an information-collection strategy which efficiently assigns applicants to such treatment classes as: selection for a specific job, extended testing, selection for a training program with deferred job assignment, rejection, etc.

Traditional viewpoints on psychological testing have rarely departed from the objective of accurate aptitude prediction. Thus, the shift toward openly facing the personnel allocation decision is to be commended, because it provides for informed management evaluations in the decision making, and because it allows a unified strategic approach that includes single-stage versus various sequential testing options, single-scaled versus multidimensional bases for outcome prediction, and the possibility of quotas and other constraints upon the decisions.

Since the strategy is a rule for arriving at a decision, the problem resolves itself into finding a best strategy based upon the return from the strategy less the strategy cost or, more simply, the payoff. However, the payoff requires a utility evaluation which is expected to differ greatly depending upon whether the decision is of an institutional or a personal type. Testing is presumed to be represented by a set of orthogonal factors based upon near-zero partial intercorrelations with respect to the payoff and zero correlations between the payoff and factors outside the basis. The expected payoff under a specified treatment then can be usefully viewed as a payoff function over the basis, and a family of payoff functions results for the set of treatments considered. Since payoff is a joint function of aptitude factors and treatments, the problem is to find a set of treatments that maximizes payoff subject to the constraints and the expected distribution of applicants over the testing basis.

Using this approach, the authors discuss in Chapter 4 the selection problem for the fixed-treatment and adaptive-treatment cases, show the differences in their effects, and demonstrate that the tests, training methods, and job organizations interact so that their best combination should be sought with respect to established payoff parameters. They then, in the next chapter, address the placement problem, and follow this with a discussion of special problems of selection and placement (such as sequential selection, selection efficiency, and bandwidth). The more complex classification problem includes both selection and placement, analogous to the familiar 'transportation problem,' and they next provide a limited approach to this problem. There follow two chapters devoted to justifications of the use of utility theory and statistical decision theory for the general arena of personnel decisions. Finally, the book contains a wide selection of supplementary works by other authors that are highly relevant of the topic and discussed by the book's authors. In particular, the selection by R. F. VAN NAERSSEN (pp. 273–290) shows that the assumption of a rectangular distribution of personnel over the test basis provides a nearly identical correspondence to the normal-distribution assumption used by the book's authors.

This book is clearly a monograph on the application of decision theory to personnel decisions that is intended to serve graduate seminars and individuals who have more than a modest acquaintance with psychological testing and applicable statistics, an objective that is well achieved. However, it is unfortunate that the authors were precluded from addressing a wider audience, from injecting the newer material into context with the general development, or from some minor niceties that would permit easier use as reference. A case in point is that the development of Chapter 4, although critical to the further developments, does not adequately equip the reader who is only acquainted with either, but not both, decision theory or classical testing procedures. However, these criticisms are minor—the book as a whole is highly recommended.

JAMES R. BUCK
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WILLIAM J. BAUMOL, *Economic Theory and Operations Analysis, Second Edition*, Prentice-Hall, Englewood Cliffs, N.J., 1965, 620 pages, $13.00

THE REVIEW of the first edition in this JOURNAL, 9(1961), pp. 759–761) considered the three chapters on programming to be the best in the book. In this second edition, the explanation of the basic theorem of linear programming has been improved in the chapter on linear programming. *Duality* is treated in a chapter by itself, and a new chapter on *Linear Programming and the Theory of Production* has been added. In the first of these two new chapters, duality is treated clearly although it is unlikely to inspire "decentralized decision-making" immediately. In the second, the author's basic orientation comes to the surface most clearly: "The analyst whose training is primarily in standard economic theory will find in the programming model a great deal that is familiar to him . . . the points of view of marginal analysis and linear programming are not so different after all" (pp. 271 and 294).

Considered as an economist's introduction to linear programming, the volume has merits. However, as the review of the first edition stated, this volume is on economic theory, *not* on operations research.

In a volume on economic theory (or perhaps more accurately, microeconomic theory), the idea of adding a chapter on *Empirical Determination of Demand Relationships* in the second edition is welcome. The straw-man analysis of the relation between advertising outlays and sales revenue brings out some of the difficulties of statistical determination of demand-supply relations, but even the appendix to the chapter merely refers to the identification problem and simply states that "restrictions of type (2)—some variables in the demand equation are absent from the supply equations—have been used most frequently in practical economic problems" (p. 232).

Similarly, the two new chapters on *Theory of Capital* and *Capital Budgeting* wind up somewhat anticlimactically with discounting by means of the compound-interest formula, and the choice of investments on the basis of the discounted present-value criterion.

It is gratifying to note that the author has expunged in the second edition two chapters objected to in the review of the first edition, thereby improving the cohesiveness of this volume.

GEORGE K. CHACKO
The MITRE Corporation

M. DRESHER, L. S. SHAPLEY, and A. W. TUCKER (editors), *Advances in Game Theory*, Princeton University Press, Princeton, N.J., 1964, 692 pages, $8.50 (paper)

THIS study carries on the tradition of the four volumes entitled *Contributions to the Theory of Games* [*Annals of Mathematics Studies* 24 (1959), 28 (1953), 39 (1957), and 40 (1959)]. It is representative of current state of game theory, now a well established science of numerous branches. The 29 papers, some of which were presented at the Princeton Conference on the subject in October 1961, are:

L. S. SHAPLEY, *Some Topics in Two-Person Games.*

RODRIGO A. RESTROPO, *Games With a Random Move.*

SELMER M. JOHNSON, *A Search Game.*

O. GROSS, *The Rendezvous Value of a Metric Space.*

HUKUKANE NIKAIDO, *Generalized Gross Substitutability and Extremization.*

JACK L. ROSENFELD, *Adaptive Competitive Decision.*

MORTON DAVIS, *Infinite Games of Perfect Information.*

JAN MYCIELSKI, *Continuous Games of Perfect Information.*

C. RYLL-NARDZEWSKI, *A Theory of Pursuit and Evasion.*

LEONARD D. BERKOVITZ, *A Variational Approach to Differential Games.*

LEONARD D. BERKOVITZ, *A Differential Game Without Pure Strategy Solutions on an Open Set.*

WENDELL H. FLEMING, *The Convergence Problem for Differential Games, II.*

LARS ERIK ZACHRISSON, *Markov Games.*

J. R. ISBELL, *Homogenous Games, III.*

L. S. SHAPLEY, *Solutions of Compound Simple Games.*

GUILLERMO OWEN, *The Tensor Composition of Nonnegative Games.*

ALBERTO RAUL GALMARINO, *On the Cardinality of Solutions of Four-Person Constant-Sum Games.*

MICHAEL H. HEBERT, *The Doubly Discriminatory Solutions of the Four-Person Constant-Sum Game.*

R. E. STEARNS, *Three-Person Cooperative Games without Side Payments.*

GERD JENTZSCH, *Some Thoughts on the Theory of Cooperative Games.*

ROBERT J. AUMANN AND MICHAEL MASCHLER, *The Bargaining Set for Cooperative Games.*

MICHAEL MASCHLER, *Stable Payoff Configurations for Quota Games.*

BEZALEL PELEG, *On the Bargaining Set M_0 of m-Quota Games.*

HANS RADSTROM, *A Property of Stability Possessed by Certain Imputations.*

EVAR D. NERING, *Coalition Bargaining in n-Person Games.*

KOICHI MIYASAWA, *The n-Person Bargaining Game.*

REINHARD SELTON, *Valuation of n-Person Games.*

ROBERT J. AUMANN, *Mixed and Behavior Strategies in Infinite Extensive Games.*

JOHN C. HARSANYI, *A General Solution for Finite Noncooperative Games Based on Risk-Dominance.*

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