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The Analyst's Bookshelf

Joseph F. McCloskey, Editor

BOOKS

Reviews

G. AVONDO BODINO and F. BRAMBILLA, *Teoria delle Code (Theory of Queues)*, Istituto Editoriale Cisalpino, Milan, Italy, 1959, 219 pages

THE FACT that this text is written in Italian will not prevent it from being a useful supplemental reference work for students of operations research and the mathematical theory of queuing. It represents a concentration of methods and results that are now widely scattered through the scientific literature of the past decade. Both of the authors are associated with the *Centro per la Ricerca Operativa* at the L. Bocconi University in Milan, and PROF. FRANCESCO BRAMBILLA is the director of that center as well as being director of the Statistics Institute at the same university.

The first part of the book is devoted to introductory fundamentals, a discussion of waiting-line phenomena, stochastic processes in general, a more detailed discussion of Markov processes, and a brief description of the simple Poisson process including the role of "*La Distribuzione Esponenziale Negativa*."

The second and major portion of the book is devoted to topics in queuing theory. The now classic theory of the queue with a single server is developed in theme and variations. The cases of (1) Erlangian arrivals and Poisson servicing and (2) constant interval arrivals and Erlangian servicing are obtained by the integral-equation route (LINDLEY). Case (1) above is also studied by the differential-equation method (FELLER). The discussion of single-server theory is terminated with a general exposition of the stochastic matrix method of solution (KENDALL). The theory of the multiserver queue is then developed, and finally, a summarization of results and a comparison of the different methods is given. The discussion of theory is concluded with the time-dependent case of the single server (CLARKE) and a very brief indication of the use of empirical distributions and simulations. Of some interest here is a reference to Italian work in queuing simulation. G. AVONDO BODINO, "*Un simulatore elettromeccanico di code*," *Bollettino del Centro per la Ricerca Operativa*, N. 7-8 (1958).

The third and concluding section of the book discusses a few applications to inventory and 'machine interference' (maintenance) problems plus a discussion of numerical methods of solution.

An excellent bibliography is appended.

DAVID S. STOLLER
The Rand Corporation

DAVID L. CONKLIN, et al., *Economics of Nuclear and Conventional Merchant Ships*, Superintendent of Documents, Government Printing Office, Washington, D. C., 1959, 840 pages, \$4.50

THIS IS a book on a subject highly important to the United States in its political and propaganda aspects, none of which is considered or even alluded to in the voluminous and highly technical text. The volume fills a need and makes a substantial contribution to our store of unclassified technical knowledge and to decisions on economic objectives in the subject it covers.

It is an effort of considerable magnitude by a large number of people. The title page lists seven persons by whom the report was 'prepared', an acknowledgment page shows some 24 additional individuals as authors of specifically named sections of the study, and there are other authors listed only in footnotes to appendices that they have prepared. The 199 pages of double spaced letter-sized multilithed text are followed by three times as many pages of appendices.

Accordingly, the reader is prepared to find and accept a certain amount of repetitiveness as each author begins his section, and even to find minor inconsistencies in viewpoint or facts. These occur. For example a graph entitled "Engine Department Manning for Conventionally Powered Passenger Cargo and Passenger Vessels" shows a plot of numbers of crew *vs* shaft horsepower. The abscissa scale is 10 times as large as the discussion in the text indicates is meant. Assuming this correction made, the chart shows ordinate values (*i.e.*, number of crew in engine rooms) as being larger than the entire crew for a cargo vessel of the same horsepower as shown in a previous section of the text. Similar unexplained inconsistencies among sections are to be found in several other places. While disconcerting, they do not appear to affect the over-all result, which shows that nuclear power for commercial use is (and for the next few years will be) competitive with power from fossil fuels only for trade routes where the ships use large amounts of energy long voyages and high-speed operations.

WILLIAM H. SUTHERLAND
Operations Research Office
The Johns Hopkins University

JAMES H. BATCHELOR, *Operations Research: An Annotated Bibliography*, Saint Louis University Press, St. Louis, Missouri, 1959, 865 pages, \$10.00

THIS TRULY monumental work is a bibliography of 4,195 references in or related to operations research published through 1957, together with abstracts prepared by the compiler, except where it was possible to reprint a suitable abstract prepared by the original author, abstracts are omitted only when the title is an adequate indicator of the contents, when the original publication was itself an abstract, or when the original publication was unavailable to the compiler. Eighty-five of the 865 pages are devoted to a carefully prepared index of about 12,000 items.

As to what the bibliography includes, the compiler has this to say in his preface:

The criterion for inclusion has been that the author or editor has indicated that the work concerns operations research or that it has been cited in support of such

work This has resulted in the inclusion of some items of dubious value and pertinence and of some cases where the term is used in a clearly different or special sense I have preferred not to exercise any editorial preferences but to let the literature of operations research define itself Foreign literature appears to disclose characteristic differences in national conceptions of operations research which serve to illuminate the possible varying viewpoints

I have included all papers from the *Operational Research Quarterly*, *Operations Research* (*The Journal of the Operations Research Society of America*), *Naval Research Logistics Quarterly*, *Management Science*, *Management's Operations Research Digest*, *Bollettino del Centro per la Ricerca Operativa*, *Revue de Recherche Opérationnelle*, *Unternehmensforschung* (*Operations Research*), *Journal of the Operations Research Society of Japan*, *Keiei Kagaku* (*Management Science*), *Operations Research Association (Bangalore)* *News Letter*, from published collections of papers and reports of meetings on operations research, and individual published papers and books wherever found To these I have added some references clearly within the spirit of the others and a few which seemed convenient or useful to include

Most of the primary publications indicated above contain references to other papers or books for supporting material or method These are included but the process has not been carried beyond these secondary references which should be followed up as desired by persons interested in the particular fields

The large amount of material involved soon made it apparent that a truly comprehensive bibliography would exceed practical space limitations and that the list would have to be restricted to operations research liberally construed to include the various equivalent terms (not by any means generally so accepted) Related specialties such as linear programming, cybernetics, and the like, already the subjects of separate bibliographies, are omitted except where actually used in operations research, as are purely mathematical derivations and proofs unless giving a solution to a specific problem

Since this new bibliography (which will be called B in what follows) appeared shortly after *A Comprehensive Bibliography on Operations Research* (reviewed in this JOURNAL, 1959, pp 540-543) and just before its 1957 supplement (reviewed below), both prepared for the Society by the Operations Research Group at Case Institute, and since both B and the two volumes prepared at Case (called collectively C in what follows) cover the period through 1957, it is natural to compare B and C

1 *Number of items* B lists 4,195 items, C lists 3,156 items through 1956 and 1,055 in 1957, a total of 4,211 However, as is discussed more in detail below, it would be a mistake to infer from these figures that the coverage of the two volumes is the same For example, as pointed out in the preface to B, related specialties such as dynamic programming are not included in it "except where actually used in operations research," whereas no such ground rule is used in C, therefore, for example, B associates 25 references with BELLMAN, while C lists 132

2 *Index* Ten per cent of the space in B is devoted to a carefully prepared index, although a ten-digit classification scheme (for a discussion of it, see the review cited above) is used throughout C, an index based on this scheme is not included, and a reader wishing to find all of the items in a given category is forced to check all 4,211 entries

3. *Information presented* C presents the author, title, and source of each reference, together with a ten-digit categorization of it, B gives the author, title, and

source, and, with the exceptions noted above, it also provides an abstract (in some cases additional information is presented, as will be discussed below)

4 *Format* Both B and the first volume of C are reproduced from carefully prepared, but unjustified, typescripts, and both are sturdily bound in cloth, the second volume of C has a similar format, but has a loose-leaf plastic binding. B has 875 pages, 5½ by 8½ inches, the first volume of C has 200 pages, the second 133 pages (but with only half as many entries per page as the first volume), both 8½ by 11 inches.

A complete comparison of the coverage of the two bibliographies would involve more of an analysis than this reviewer was prepared to undertake. However, perhaps the results of the following analysis of the entries under the first letter of the alphabet suggest at least the sorts of result that a more complete analysis would produce.

1 Under the letter A, B has 181 entries, of which 90 are duplicated in C, and C has 148, of which 102 are duplicated in B (the difference between the 90 and the 102 arises from several variations in listing practice between the two bibliographies, thus, when several reports on the same research appear, each is given a separate entry in C, but the items are grouped under a single entry in B). These data suggest that, while the two bibliographies have a substantial overlap, each contains also a substantial number of listings not contained in the other.

2 To determine the character of listings contained in one but not the other bibliography, the reviewer developed the following data (the classification being made on the basis of a rough judgment made quickly from the available evidence). Of the 46 items listed in C but not in B, 10 were in the 'related specialties,' which were excluded from B by decision, one was a substantive operations-research paper, and 35 were what the preface to B called "secondary references," that is, items of supporting or tangential relevance whose inclusion might well depend on the breadth of judgment being used by the compiler. Of the 91 items listed in B but not C, 15 were titles of abstracts of papers dealing with research not published in full elsewhere before the end of 1957, 19 were items of news and discussion dealing with operations research as an activity rather than with the results of substantive research, 16 were substantive operations-research papers, and 41 were secondary references. These data suggest the following conclusions: (a) The two bibliographies agree very well on, and both list, the items that may be regarded as central to operations research, with a few additional substantive operations-research listings in B that are not in C. (b) C includes many listings in the area defined by B as "related specialties" and not listed in B. (c) On the other hand, B lists two categories of material not included in C: titles of abstracts dealing with research not reported on in full by the end of 1957, and items of news and discussion dealing with operations research as an activity. (d) The chief divergence of the two listings is in their secondary references (as could well be expected, since few operations-research workers would agree in this area in any case).

A number of special features of the Batchelor bibliography add to its interest and usefulness.

1 When several publications have appeared that deal with the same research effort, they are collected together under a single entry, for example, for Thorntwaite's classic work on operations research in agriculture, the bibliography lists four published versions, plus four summaries published elsewhere. Too, wherever

possible, an early published abstract of a paper is always associated with its later full published version

2 Reviews and comments on publications are also listed under the entry for the original publication. For example, for MORSE AND KIMBALL's *Methods of Operations Research* the bibliography lists 10 reviews and comments

3 The abstracts conclude by listing the number of references provided by the original article. For example, the abstract of SAATY's *Resume of Useful Formulas in Queuing Theory* (published in this JOURNAL, 1957, pp. 161-200) shows that it provides 68 references, a valuable indicator of its importance as a review article

Obviously, the value and usefulness of a bibliography depends upon the care, completeness, and good judgment used in preparing the index. While this reviewer cannot claim to have subjected the index in the Batchelor volume to a complete and critical analysis, he can say, after much repeated use, that it has not failed him. In short, the index appears to be up to the high standard of the rest of the volume

In sum, this new volume is a monumental achievement, particularly when one considers that it was prepared almost entirely by one man relying principally on his own resources. Batchelor has placed every operations-research worker permanently in his debt, the reviewer intends as sincere and forceful the elsewhere trite statement that every worker in our field should have a copy of this invaluable book at his elbow. In addition to providing convenient and effective help, he will find it a pleasure to browse in, as well as a source of much education in operations research

But, since this volume covers the period only through 1957, what of 1958 and succeeding years? The reviewer is happy to report that Batchelor is continuing his important work, and that an agreement has been reached involving the SOCIETY, the Case Operations Research Group, and Batchelor to transfer the SOCIETY's support to Batchelor's effort. Therefore, we may look forward at intervals to companion volumes for periods following 1957. In the meantime the Case group will complete and publish its almost-finished listing for 1958. The ten-digit classification scheme used in the Case bibliographies will be carried over into Batchelor's future work to enable the continuance of the arrangement whereby punched cards and sorting equipment can be used in association with the bibliographies

HUGH J. MISER

The Research Triangle Institute

Operations Research Group, Case Institute of Technology, *A Comprehensive Bibliography on Operations Research*. 1957, Case Institute of Technology, Cleveland, 1959, 123 pages, \$2.00

THIS multithed, loose-leaf book is a supplement to *A Comprehensive Bibliography on Operations Research*, Publications in Operations Research No. 4, John Wiley and Sons, Inc., New York, 1958 (reviewed in this JOURNAL, 1959, pp. 540-543). This new volume increases the 1957 listings of the earlier one from 207 to 1,055. The ten-digit classification scheme of the earlier publication is continued and the listings are arranged alphabetically by author as before with one

exception. Although the foreword points out that "foreign-language" publications are listed separately and given special identifying serials, these publications are actually included in the alphabetical listing, which also contains English-language publications, and the special identifying serial is not used. There are no special bibliographies similar to the ones in the earlier volume. The preparation of this bibliography was supported by a grant from the Office of Scientific Information of the National Science Foundation.

HUGH J. MISER

The Research Triangle Institute

SIDNEY SOBELMAN, *A Modern Dynamic Approach to Product Development*, OTS, U. S. Department of Commerce, Washington, 25, D. C., 1958, 205 pages, \$3.50

THIS ambitiously titled work is one of a number of studies prepared "under the auspices of a Secretary of the Army's Research and Study Fellowship."

It is a difficult monograph to evaluate. The literature search represented is unusually thorough for this day and age, but there are some interesting gaps suggesting that the search ended significantly before the December 1958 publication date. The author draws heavily on the literature and quotes extensively. Because the book is reproduced from a typescript however, and because the proofreading leaves something to be desired, it is sometimes difficult to distinguish between the author's thoughts and those of his references.

The author is at his best when he quotes most extensively in that he has done a rather good job of reviewing the literature and bringing out the salient conflicts of opinion and approach. Where he is 'on his own' this reviewer got the feeling that he is much more academic than practical. It is difficult to imagine any research and development agency, government or industrial, leaping on the bandwagon of acceptance of his method. Given adequate data, there is little doubt but what his method would improve the management of a research and development effort. But the data problem is, in this reviewer's opinion, the central problem in this area and the author makes little or no contribution to ways and means of overcoming this problem.

In sum, this is a good effort primarily as a review of the problem. It does not appear to be 'the answer' to the problem.

J. F. M.

Books Received

CANADIAN OPERATIONAL RESEARCH SOCIETY, *Proceedings of the First Annual Conference, University of Toronto, May 1959*, Mr. Peter J. Sandiford, Canadian Operational Research Society, Trans-Canada Airlines, International Aviation Bldg., Montreal, Canada, 1959, 50 pages, \$2.00.

ROBERT G. BROWN, *Statistical Forecasting for Inventory Control*, McGraw-Hill Book Co., New York, 1959, 232 pages, \$7.75.

WALTER ISARD, EUGENE W. SCHOOLER, AND THOMAS VIETORISZ, *Industrial Complex Analysis and Regional Development*, The Technology Press, Cambridge, Mass., and John Wiley & Sons, New York, 1959, 294 pages, \$8.75.

- EZRA SOLOMON, Ed., *The Management of Corporate Capital*, The Free Press, Glencoe, Illinois, 1959, 327 pages, \$7.50
- ULF GRENANDER, Ed., *Probability and Statistics, The Harald Cramér Volume*, John Wiley & Sons, New York, 1959, 434 pages, \$12.50
- MORDECAI EZEKIEL AND KARL A. FOX, *Methods of Correlation and Regression Analysis*, Third Edition, John Wiley & Sons, New York, 1959, 548 pages, \$10.95
- HENRY SCHEFFÉ, *The Analysis of Variance*, John Wiley & Sons, New York, 1959, 477 pages, \$14.00
- LEON K. KIRCHMAYER, *Economic Control of Interconnected Systems*, John Wiley & Sons, New York, 1959, 207 pages, \$12.50
- RENATO CONTINI AND PAUL T. BRYANT, Eds., *Engineering College Research Review 1959*, Engineering College Research Council, American Society for Engineering Education, University of Illinois, Urbana, Illinois, 1959, 445 pages, \$2.00
- STEPHEN H. CRANDALL AND NORMAN C. DAHL, Eds., *An Introduction to the Mechanics of Solids*, McGraw-Hill Book Company, New York, 1959, 444 pages, \$8.50
- MARK B. MOORE, *Theory and Application of Mechanical Engineering Measurements*, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1960, 296 pages, \$6.75

Comments

THE *Proceedings of the First Annual Conference* of the Canadian Operational Research Society is a most informative volume. Consciously or not, the planners of the Conference arranged for the presentation of what appears to be a well-balanced cross section of current OR in Canada. In this reader's opinion, the most striking conclusions to be gleaned from the summaries included in the *Proceedings* are the extent to which Canadian work is oriented to large- and medium-size computers and the extent to which planning-type activities dominate. In fact, there are pleas for greater attention to studies of on-going operations aimed at deriving the greatest effectiveness from in-place equipment.

The highlights of the *Proceedings*, apart from the summaries of the papers given during the regular sessions, are a description of a new curriculum in operations research at the University of Toronto, OMOND SOLANDT's Presidential Address, and ELLIS A. JOHNSON's banquet speech (reprinted in full).^{*} In the latter two, there is strong emphasis on the need for retaining, developing, and extending the *research* aspects of operations research, with the suggestion that *practice* may well be passing into the hands of industrial engineers, management consultants, and managers.

THE HARALD CRAMÉR VOLUME consists of studies in probability and statistics (prepared by a list of authors that comes close to 'who is *really* who' in the field) in honor of Harald Cramér on the occasion of his sixty-fifth birthday. There are nineteen essays in all; the fact that they are arranged alphabetically by author is indicative of their independence of each other.

THE EZEKIEL-FOX book is divided into seven sections, plus three appendices. It covers Introductory Concepts; Simple Regression, Linear and Curvilinear; Multiple Linear Regressions; Multiple Curvilinear Regressions; Significance of Correlation

^{*} See *Opns. Res.* 8, 1-23 (1960).

and Regression Results; Miscellaneous Special Regression Methods; and Uses and Philosophy of Correlation and Regression Analysis. The appendices include a glossary and important equations, methods of computation, and technical notes. The book is thoroughly documented and emphasizes practical applications.

SCHEFFÉ's *Analysis of Variance* is divided into two major sections: "The Analysis of Variance in the Case of Models with Fixed Effects and Independent Observations of Equal Variance" and "The Analysis of Variance in the Case of other Models." Of the two parts, the author says (Preface), "The theory of Part I . . . I judge to be jelled into a fairly permanent form, but the theory of Part II . . . I expect will undergo considerable extension and revision." His objective (Preface) is to elucidate "in a unified way what appears to me at present to be the basic theory of the analysis of variance."

Economic Control of Interconnected Systems is concerned with mathematical methods, computers, and controls to obtain optimum operation of interconnected electric utility systems.

Engineering College Research Review gives complete titles for all projects underway in schools that hold Engineering College Research Council membership; in addition, numbers of research personnel at each institution are listed, and research policies are summarized. There is a complete index of research project subjects, to help locate activities in similar fields at different institutions. Some 10,000 projects at 118 institutions with an aggregate value of more than \$112 million are listed.

PERIODICALS

Selected Contents

Journal of Industrial Engineering, November–December 1959 (Selected articles)

RAYMOND VILLERS, *The Scheduling of Engineering Research*

STUART L. KNOWLTON, *A Simplified Approach to Waiting Lines*

WARREN R. MELLIN, *What is an Organized Methods Improvement Program?*

C. M. SHETTY, *Solving Linear Programming Problems with Variable Parameters*

EUGENE RICHMAN AND SYLVAIN EHRENFELD, *Industrial Engineering Techniques and Operations Research*

FRANCIS L. CANNING, *Estimating Load Requirements in a Job Shop*

JOHN A. RITCHEY, *An Unusual Work Sampling Application*

OWEN GILBERT, *A Biologist in Steel*

A. E. ROKHSAR AND G. E. KANE, *The Effect of Hypergeometric Probability Distribution on the Design of Sampling Plans for Small Lot Sizes*

And Some Notes

THE *Documentation Bulletin* of the International University Contact for Management Education (Delft, The Netherlands) for October, 1959, carries a description of the new curriculum in Principles of Industrial Management recently introduced at Cambridge University. It is written by F. J. WILLET, of Cambridge, under the title, "A New Approach to Teaching Industrial Management."

RAOUL J. FREEMAN has published two articles on the use of mathematical models and electronic computers in the field of real estate assessment. One is "A Note on Assessment Automation" in the *Journal of Land Economics* for November 1959 and the other is "Real Estate Assessment and Electronic Computers" in *Appraisal Journal* for April 1959.

R. W. CONWAY, B. M. JOHNSON, AND W. L. MAXWELL report on "A Queue Network Simulator for the IBM 650 and Burroughs 220" in *Communications of the ACM* for December 1959.

Business Week for November 28 describes 'power casting' developed by Westinghouse Electric Corporation. The term 'operations research' is studiously avoided in the article but the concept, techniques, and interpretations are operations research.

E. N. GILBERT writes on "Optimal Search Strategies" in the December 1959 issue of the *Journal of the Society for Industrial and Applied Mathematics*. He considers the situation where the searcher switches his effort between two sources of the item sought. His model seeks to minimize expected time spent searching, including the time spent in switching.

ABSTRACTS OF THESES

***Properties, Models and Solutions of Elementary Inventory Systems and Their Extensions*, by ELIEZER NADDOR, Ph.D. in Operations Research, Case Institute of Technology, June 1957, 95 pages, Case Institute of Technology Library (available on loan)**

INVENTORY systems (involving the decision problems when to produce or order and/or how much to produce) in which the costs of surpluses, shortages, and setups are subject to control, are defined and a methodology for solving these systems, as extensions of elementary systems, is presented. The properties of inventory systems—input, scheduling period, output, units, costs—are recognized and numerous possible variations of these properties are discussed.

The initial models given represent systems with simple properties. They are used to establish starting points for further extensions, to illustrate methods for obtaining the total cost equations and their solutions, and to establish standards for comparisons with other more complex systems. The extensions of the initial models deal with effects of balancing surplus, shortage and setup costs, discrete units, input and output patterns, several items, and variability of output and lead time. For all extensions solutions are obtained and the results compared. Some numerical illustrations are given.

The effects of deviations from optimal solutions and the effects of use of estimated parameters are discussed and numerical illustrations illuminate the significance of the results obtained.

The case studies presented deal with (1) the inventorying of materials and (2)

the training of new employees. The inventory systems are analyzed in detail, using the methods developed earlier.

The work is summarized and concluded with remarks on the use of the work and problems for further research. The bibliography lists books, articles, and general surveys pertaining to inventory systems.

***Competitive Bidding Strategies*, by LAWRENCE FRIEDMAN, Ph.D. in Operations Research, Case Institute of Technology, June 1957, 122 pages, Case Institute of Technology Library, published as a research report of the Operations Research Group, Case Institute of Technology**

COMPETITIVE bidding is formulated as a problem in decision theory that can be analyzed by game theoretic methods. The meaning of competition is discussed and the interrelations among competitors defined by introducing a competitive coefficient. Some simple auction and closed-bidding problems in which there are two competitors with limited capital are solved exactly using the minimax principle. Methods of analyzing real bidding problems are given, including a paraphrased case study of an actual bidding situation. A general approach to realistic bidding problems is described using the Bayes Theorem of decision theory. The future of competitive bidding in operations research is discussed with particular mention of problems yet unsolved.

***An Experimental Investigation of Scheduling for Single-Stage Production*, by RICHARD WALTER CONWAY, Ph.D. in Industrial and Engineering Administration, Cornell University, February 1958, 166 pages, Cornell University Library (available on loan)**

SCHEDULING for single-stage production may be simply described as the task of sequencing the work for a facility that has several things to do but which can do only one thing at a time. In practice some form of priority rule is often used to determine the product sequence. The author attempted to extend this concept and develop a priority system that would simultaneously determine sequence and lot size—specify when to change over to another product as well as which product should be produced next. Several such rules were developed and tested empirically, by means of simulated experimentation on a digital computer. To accomplish this, a program was prepared for an IBM 650 computer that simulated the operation of a single-stage production facility.

These tests demonstrated the feasibility of extending the use of priority rule scheduling. The results indicate that the difficulty in scheduling for single-stage production increases with an increase in

- 1 The relative load on the facility
- 2 The unbalance between the amounts of the different products that are produced
- 3 The number of products that must be produced on a single facility

The interdependence of the lot sizes for different products and the strong dependence

of lot size upon the load on the facility is clearly demonstrated. The existence of an economic capacity of a single-stage facility that is less than its physical capacity is indicated. This economic capacity is a point beyond which additional production, although possible, is not profitable since the incremental costs are greater than the incremental revenue.

The medium employed—digital simulation—promises to have great significance for both research and practice in industrial engineering. Some of the abilities, characteristics, and limitations of this technique are critically discussed.

***Programming Under Uncertainty*, by SALAH E. A. ELMAGHRABY, Ph.D. in Industrial and Engineering Administration, Cornell University, September 1958, 168 pages, Cornell University Library, adapted version appeared in *Operations Research*, 7, 208–216 (1959)**

THE PROBLEM of allocation of resources when the demand is stochastic in nature was treated by G. B. DANTZIG in 1956. The solution that he offered is limited to a special class of problems, namely, to problems of allocation (with unit coefficients of the variables in the linear restrictions), when the demand is discretely distributed, and its cumulative distribution function is estimated by 'point' estimates.

In this thesis, all three of these restrictions are weakened. The solution of the allocation problem in the case of continuous demand distributions is presented in Chapter III. A necessary and sufficient condition for optimality is given, together with an iterative algorithm of solution. Thus, starting with any allocation (preferably a good 'guess'), the procedure moves stepwise towards the minimum-cost allocation, which it is guaranteed to obtain.

The general programming problem (with arbitrary coefficients in the linear restrictions) is also treated in Chapter III, but only for discrete demand distributions. The reason for such a limitation is the fact that the problem is transformed into a linear-programming one, with upper bounds on the transformed variables.

The problem of programming when the probability frequency function of demand is estimated by means of an interval is treated in Chapter IV, where an analytical solution of the game-theoretic interpretation of the problem is presented. Because of the computational difficulty of the analytical solution of such problems, a study was undertaken to investigate the feasibility of solution by analog computer methods. The results of the investigation show that an analog computer would be a valuable tool for such studies, though the accuracy of the solution suffered because of the inherent characteristics of the electronic components used.

Study of the programming and allocation problems is prefaced with a brief review of current literature, presented in Chapter I, and a discussion of two important topics that have considerable philosophical as well as practical impact on programming theory, presented in Chapter II. These topics are Criteria for Decision, and the Notion of Utility. The study offered a rationalization of the decision criteria used in the sequel, and led to certain conclusions that have implications in the many fields of decision that are included in the general area of operations research.

***Computer Models of the Shoe, Leather, Hide Sequence*, by KALMAN JOSEPH COHEN, Ph.D. in Economics, Graduate School of Industrial Administration, Carnegie Institute of Technology, June 1959, vi + 101 pages, 49 charts, Carnegie Institute of Technology Library (available on loan)**

THIS thesis discusses the construction of two mathematical models describing the aggregate behavior of shoe retailers, shoe manufacturers, and cattlehide leather tanners between 1930 and 1940. The BLS consumers' price index, disposable personal income, and the stocks of hides held by hide dealers are the chief exogenous variables. The major endogenous variables are the retailers' selling price, sales, and shoe receipts, the manufacturers' selling price, production, and leather receipts, the tanners' selling price, finished production, hide wettings, and hide receipts, and the hide dealers' selling price.

The mathematical form of the models is a complex, nonlinear system of lagged simultaneous difference equations subject to boundary constraints, with one month as the basic time period. The models are designed for simulation rather than analytical solution, hence an electronic digital computer is used to trace out the time paths from 1930 to 1940 of each endogenous variable. One of the models, a "one period change model," is intended to explain the values of the endogenous variables for only one time period ahead into the future, this model assumes, as is usually done in econometrics, that lagged endogenous variables refer to their actually observed values. Our other model, a "process model," is designed to explain the determination of the endogenous variables for an arbitrarily large number of future time periods. The equations of the process model, together with the observed time paths of the exogenous variables, are treated as a closed dynamic system, each month, the values of the predetermined endogenous variables are the values generated by the model, not the actually observed values. The methodology of this 'closed dynamic system' approach, i.e. of process models, is compared with the methodology underlying the one-period change models that are traditional in econometrics, with particular attention being paid to the problems of parameter estimation and of validation, i.e., 'goodness of fit,' of the models.

The time paths of the major endogenous variables, which are traced out by both models, are compared with the observed time paths of these variables from 1930 through 1940. The results indicate that comparisons on an annual basis show a very close correspondence between the time paths generated by our process model and the actual values. While our models do not provide a completely acceptable monthly aggregate level description of the shoe, leather, hide sequence between 1930 and 1940, the evidence provided by the annual comparisons is consistent with the hypothesis that the models incorporate some of the mechanisms that determined the behavior of individual firms in these industries (although no precise statistical tests have been made).

***A Class of Stochastic Investment Problems*, by JAMES L. FISHER, Ph.D., in Operations Research, Case Institute of Technology, June 1959, 102 pages, Case Institute of Technology Library (available on loan)**

A DECISION MAKER, faced with investment opportunities that occur throughout time, must, when confronted with a particular investment, decide

whether to accept the investment. The problem of determining optimal decision rules under these conditions is formulated as a stochastic process that can be analyzed by the functional equations of dynamic programming. Investment opportunities are first considered to occur at regular intervals in time. This is then generalized so that, in the limit, opportunities can occur at random. Some simple investment problems involving a decision maker with fixed assets are solved and numerical results presented. As an extension of these simple situations, a problem of investing a stream of assets is solved. As an illustration of the methods, two numerical problems based on business applications are solved and optimal decision rules presented.