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Toward an Understanding of Operations Research Concepts

Harold W. Fox

Although today's accountant finds himself increasingly involved with OR, very often the books and articles on the subject are unintelligible to a nonmathematician. Here is a reading list demanding no mathematics—

TOWARD AN UNDERSTANDING OF OPERATIONS RESEARCH CONCEPTS

by Harold W. Fox
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THE proliferation of quantitative methods in print and practice faces consultants with an ever-growing challenge. Operations research has been hailed for showing the way to dramatic productivity increases or cost savings in virtually all areas of defense and business activities, especially production and physical distribution. As operating executives hear about linear programing, queueing theory, nonabsorbing Markov chains, and other techniques of operations research (OR), they naturally look to their staff people and external advisers for a "quick rundown" on or even a demonstration of this mysterious art.

OR tools are designed to discover procedures that minimize inputs or maximize outputs, a function that is outside the province of routine accountancy. But there are many compelling reasons why accountants and other members of management have to be familiar with these modern approaches to problem solving.

Operations research is interdisciplinary. OR men draw on biological principles, information theory, physics, or whatever analogies advance a solution to the problem at hand. The rapid tempo of new discoveries in the sciences amplifies the power of OR, and the emergence of new business problems that seem insoluble by conventional methods assures the need for it.

Operations researchers depend on accounting for cost data, one of their important inputs, which they reformulate to fit their techniques and purposes. Increasingly, the resourcefulness of accountants and OR specialists, the ingenuity of programers, and the prodigious capacity of computers provide accounting information and mathematical processing that make the complex and comprehensive approach of operations research workable.

Different from accounting

Persons whose work is anchored to the equality of debits and credits might regard OR thinking about requirements and restrictions as heresy. Requirements and restrictions are stated as ranges, limited on one side and open on the other. Instead of an equation, an OR formula is often an inequality. It may require revenues of at least, and restrict costs to no more than, some particular amount.

Again, operations researchers might translate accounting data into opportunity costs, the loss due to foregoing the best of various possible choices of action. Whereas accountants use point estimates, OR men often employ probability. The single amount that is an account entry is replaced by several, each multiplied by the likelihood of its occurrence. The probability values may reflect theory, experience, or executive judgment. Special studies develop nonaccounting statistics. Random numbers are used for projecting operational systems whose structure has been reduced to a model.

Sometimes a lack of accurate data can be overcome. A mathematician depicts the major influences on profit (or some other objective) by means of symbols and their relationships. The results may be usable over a designated range of operations, even though actual cost and revenue information is absent.

An OR project does not halt at the border of a cost (or profit or investment) center. It tries to encompass all significant interconnections; ideally it stops when the cost of additional effort is not commensurate with the expected value of additional information. After a study, sensitivity analysis of the results measures the importance of various elements in the solution. OR solutions often indicate the maximum profit or minimum cost, but they also may be couched in terms of utility, the degree to which an objective is achieved.

Although more examples could be given, it is evident that OR purposes and practices differ from those of accountancy. This does not eliminate the possibility that a study of operations research might uncover some techniques that could become useful additions to the accountant's own business repertoire.

Operations researchers can be expected to welcome an accountant's active participation in their projects because teamwork is a major tenet of OR philosophy. A conceptual understanding of their work propels the accountant into a creative role. He is in a position to suggest valuable data sources and interpretations that are unknown to nonaccountants.

Complementary to accounting

An accountant with a grasp of OR can be valuable to his employer or client. He can press for the adoption of OR where it may be useful, and he can discourage its misapplication. Since OR, like accounting, employs quantitative methods, it has some inherent limitations similar to those of accounting. Its domain is confined mainly to tangible, measurable factors. Like computers, OR has sometimes been oversold. Its capacity is often under-utilized. There is no sense in appropriating huge amounts of money and executive time if the climate is not right for use of the findings.

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Even where OR techniques are workable, the dynamics of business may make the results unreliable. An accountant who is able to foresee radical changes in applicable equipment and other resources, product lines, business objectives, public attitudes, laws, or competitive strategies can forestall an expensive study that will soon be obsolete. Often, especially when the OR team consists of scientists with no practical business experience, an accountant can check the validity of the research and the commercial soundness of the recommendations. Moreover, he can make the final report more comprehensible to operating executives.

Form versus content

As a by-product of delving into operations research, a layman will gain rewarding insights into structural similarities among seemingly

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disparate problems. It may be obvious that inventory control resembles cash budgeting, but . . . servicing of machines? . . . room reservations in a hotel? . . . training of airline stewardesses? Operations researchers classify a project according to its form, not its content. The emphasis is on structural analysis.

In the cases cited the common structural form is cost behavior. What are the effects of increases in the volume of inventory or the size of a checking-account balance or the number of overhauled machines, available rooms, or qualified trainees? Such increases in "contents" increase various types of carrying costs, including opportunity costs. But they also reduce costs, because of fewer shortages, less need for special preparation, greater stability, and economies of scale. Hence, problems with these formal characteristics, regardless of operating area or contents, can be solved with an inventory model.

Beyond a new way of looking at processes, a nonmathematician studying OR finds a new way of looking at himself and his clients. When the going gets a little rough and the temptation is strong to rationalize that the subject is not important anyway, he experiences the same feelings that some operating executives have toward accounting reports or flow charts. With persistence, he may discover ways to make strange material more palatable to himself—and to others.

A painless exploration

To a nonmathematician a serious effort to achieve a conceptual understanding of operations research can be a frustrating exercise. In the words of one executive (an expert on computers, by the way): "I am sick and tired of OR texts for the reader without mathematical background. They insult my intelligence by beginning with an explanation of grade school arithmetic. And six pages later, amidst differential equations, beta density functions, or the adjoint of a matrix, I am completely lost."

Yet some comprehensive, readable sources do exist. The busy executive needs a guide to lead him from a level where he can start comfortably to the point where his quest for understanding is satisfied. To fill this need, this article presents a reading plan, ascending from surveys of basic concepts to applications of simplified techniques. None of the following books requires prior knowledge of matrix algebra, calculus, or statistics.

Basic concepts

A person who seeks to understand the rationale of operations research might well start with a concise explanation, entirely narrative in form, written by Russell L. Ackoff and Patrick Rivett, two pioneers in the field. Called *A Manager's Guide to Operations Research,* this short Wiley book delivers exactly what it promises. It identifies OR's three essential characteristics as (1) systems orientation, (2) interdisciplinary teams, and (3) scientific method.

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The systems approach, these authors point out, runs counter to the research and managerial tradition of isolating some aspect of a problem for intensive study. Rather, the operations researcher encompasses all significant internal and external relationships as an entity. He represents this entity's content, structure, communications, and control in a mathematical or analogical model that describes its performance.

Organized men, machines, materials, and money constitute the contents of a system. Structure is the organization or interrelationships of all activities that contribute in an important way to the entity's objectives. Communication refers to the flow of information, an area where the work of operations researchers often overlaps that of systems and procedures or organization and methods analysts. Control has the familiar meaning of signaling and correcting material deviations from a norm.

Although construction and manipulation of models are central to OR, this work is not necessarily dominated by mathematicians. The authors nominate a physical scientist and an engineer as the first two members of an ideal OR team. Interestingly, a cost analyst ranks last, No. 7, and no other area of business administration is represented. A typical project should engage the primary attention of three scientists with diverse backgrounds, employing insights from as many different disciplines as possible.

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Models

Such a composition of OR personnel favors the use of the scientific method. Full-scale or laboratory experiments are not feasible, but symbolic ones are. Modeling is, of course, basic in operations research.

Every OR model has the same format: Performance depends on important uncontrolled and controlled variables. First, all important relationships are represented by equations (sometimes by inequalities, as noted). Second, the equations are solved by seeking those values of controllable variables that are best (or optimum) according to the performance criterion. The solution quantifies the dependence of the controllable on the uncontrollable variables. It indicates the optimal actions under a reasonable variety of conditions.

Third, repetitive trials of the equations, with the uncontrollable values altered randomly, is the OR way of conducting experiments. This is called simulation. The final step is to translate the solution into clear operating instructions.

The Ackoff-Rivett book performs a useful service to the layman by classifying all OR formulations into eight categories. The authors describe the principal characteristics of each and illustrate how it has been applied to diverse operations in many industries. The first category on their list is the inventory model. The earlier example of converting budgeting, repair, bookings, or training problems to inventory form was based in part on this book.

There is no direct correspondence among business operations, structural forms, and mathematical techniques. The underlying pattern of a business activity determines the choice of the operations research form or forms. The latter will enlist a number of mathematical techniques, like linear programing, for example. Neither the categories nor their terminologies are uniform, but most introductory classifications are similar. Of the eight forms that these authors identify, seven are also included in the next book to be discussed.

Decisions, decisions

A person who does not mind a few illustrative OR techniques will probably enjoy *The Executive Strategist* by Robert C. Weisselberg and Joseph G. Crowley. Subtitled "An Armchair Guide to Scientific Decision-Making," this McGraw-Hill book expands with a light touch on various OR topics. Its presentation also is mainly narrative. Incidental symbols and equations are defined in clear English. By outlining the structural forms, this book helps the reader to compare and apply them.

The authors distinguish among four types of environmental conditions in decision making. In the first case, certainty, the uncontrollable variables are known. Most accounting problems are of this type, e.g., a choice among existing facilities. If the uncontrollables are not known, but each of several values that they might assume has a reasonably trustworthy likelihood, the condition is one of risk. Selections of new equipment with known performance histories come to mind.

The third type, conflict, postulates an active antagonistic environment. An example is the possible reaction of a labor union to automation. Finally, uncertainty is the state where neither experience nor judgment gives usable clues to assess the uncontrollable. The date of a new equipment's technological or market obsolescence might fit this category.

Attempts to solve these types of problems optimally raise both philosophical and mathematical issues. The thinking and the methods to deal with these issues are demonstrated by easily understandable examples. A reader of this book receives an introduction to the framework and the best known quantitative techniques of OR. A person who wants to develop a deeper understanding has to work out some problem examples.

Quantitative methods

A survey of mathematical methods for a businessman who barely remembers high school algebra is available in the delightful Pelican paperback, *Mathematics in Management* by Albert Battersby. Several features make it particularly suitable for serious but busy executives.

This book stimulates the reader's involvement through brief exercises as part of its step-by-step explanation. But, unlike programed texts, it has a smooth-flowing presentation, and a person who seeks merely an intuitive grasp can pass up the questions. Solutions appear at the end of each chapter.

Helpful diagrams abound. These show procedures, translate equations into graphs, or highlight the important aspects of a problem. Another valuable feature is emphasis on the meaning rather than the mechanics of the procedures.

After an introductory chapter, Mr. Battersby explains network analysis (PERT), graphing, algebraic and graphical techniques of linear programing, the transportation method, simulation, computers (in a discussion too elementary for most readers of this magazine), and miscellaneous topics. The last include brief glimpses of changing curved into straight lines, finding economic ordering quantities, using calculus, and applying Markov chains. In a self-study program, *Mathematics in Management* would provide an easy transition from general surveys to formal texts.

Formal texts

Of some three dozen formal texts screened, two are noted here. Either can serve as a springboard to specialized treatments of business functions or mathematical methods. There are various OR-centered books on production, marketing, and so forth. And, of course, each method is treated in depth in numerous mathematics texts.

The clearest presentation among the texts surveyed is provided by Richard I. Levin and C. A. Kirkpatrick in *Quantitative Approaches to Management.* Simple words explain every table, graph, and formula. Diagrams illustrate new concepts introduced in this McGraw-Hill text. As a result, a reader virtually glides into vectors, determinants, and matrices and applies them with unexpected ease.

First, familiar material on break-even analysis is clothed in high school algebra. Simple examples help acquaint the reader with the authors' style and notation. There follows an introduction to probability theory, including decision trees and Bayes' theorem. One use of these methods is to estimate the likelihoods of various possible consequences of a decision and to revise these likelihoods with the advent of new information. This approach is extended to several types of inventory problems.

Linear programing, a technique for optimum allocation of scarce resources when input-output relationships are known and can be approximated by straight lines (planes or hyper-planes), is treated graphically and algebraically. In contrast, queueing problems (waiting lines)—with arrival and service times not certain—enlist statistical methods. The authors explain the use of simulation when applied to

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Following an OR approach, the author constructed a "decision matrix" to help him in his choice of a new textbook. Surprisingly, a different text from the one originally preferred emerged as best. Although the weights assigned to each criterion were changed in order to test the effect of changes in these values, the same book prevailed . . . even elementary decisions where the choice appears to be obvious can often be improved.

solution of a queueing problem.

Another section explains enough about matrix algebra to note its role in linear programing and to use it in game theory and Markov analysis. Game theory applies under conditions of conflict. Although conceptually simple and interesting, game theory is rarely serviceable in practical situations, because of their complexity. Markov analysis is often applied to stable processes, such as movements among different areas.

Both of the last-mentioned books can be recommended for their clear exposition of selected quantitative methods. But they cannot satisfy the person who wants an overview of all those aspects of operations research that can be absorbed without mathematical training. The text for him is *Executive Decisions and Operations Research* (Second Edition), by David W. Miller and Martin K. Starr.

This massive Prentice-Hall work presents both theoretical, philosophical analyses of decision making and OR applications in production, marketing, and finance. Because of this functional organization, some techniques are demonstrated in different contexts. Different versions of linear programing, for example, appear in all three functional areas as well as in the theory sections. A large number of OR methods are worked out or at least mentioned.

As each new method is introduced, the book gives the necessary background. Little is taken for granted. A few pages with somewhat demanding material can be omitted without loss of continuity. The explanations of mathematical techniques are straightforward, and the careful reader will not lose his way.

The text expounds the accomplishments that are possible through the use of data, models, and orderly decision making. It does not neglect to treat the limitations of OR and, indeed, human judgment. This material will enthrall the reflective reader, but the escalation of language may try his patience. Adjustment to the exposition is worthwhile. By the time a reader confronts on page 371 the statement that "marketing problems are prone to serious temporal suboptimization," the book has already alerted him to the inconsistency between emphasis on immediate profit and highest income in the long run.

Beyond initial orientation

Most of the works cited contain bibliographies and footnotes that can guide a reader to advanced treatments. Depending on his interests, he can pursue the subject through various specialized publications. Discussions with OR practitioners may prove stimulating and instructive. But he will assimilate the new material best by applying it.

The following example, though trivial, illustrates an OR type of approach. Recently the writer of this article tentatively chose a new textbook. Before committing himself, he constructed a "decision matrix" in which the alternatives were evaluated against weighted criteria. (The criteria included scope, readability, problems, etc.) Such an exercise forces the decision maker to make the criteria and their relative importance explicit and to adduce the relevant information.

Surprisingly, a different text from the one originally preferred emerged as best. Thereupon the writer made a "sensitivity analysis." He altered the weights assigned to each criterion in order to test the effect of changes in these values. Still, the same book prevailed. As this experience illustrates, even elementary decisions where the choice seems to be obvious can often be improved.

But an operations research model cannot always help the decision maker to react constructively to an unforeseen fundamental change. It so happened that the class was cancelled. The only output of the project was one not considered in the original matrix—this article.