Decision Making Through Operations Research

SECOND EDITION

Robert J. Thierauf
Robert C. Klekamp

WILEY INTERNATIONAL EDITION

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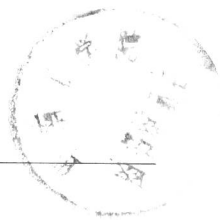

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Preface

The primary purpose of the second edition, like the first, is to present the **current** techniques of operations research in such a way that they can be readily comprehended by the average business student taking an introductory course in operations research.

The structure of the new edition is strengthened because it follows a more logical sequence for presenting a comprehensive treatment of standard operations research techniques. It focuses initially on an overview of operations research, followed by a presentation of standard OR models that employ probability and statistics, matrix algebra, calculus, simulation techniques, and advanced topics in their solution. A brief look into the future of operations research concludes the book. A fictional but typical-type manufacturing firm, the American Products Corporation, is used as the central example at the end of each chapter.

The book can be used for any convenient time period—one quarter, one semester, or the entire year. Chapters can be omitted without destroying the unity of a course since each chapter has been written to stand on its own. This allows for a wide variability of emphasis for each major topic covered.

The problems at the end of each chapter are designed to challenge the reader's understanding of the subject matter. Answers to the problems can be checked by referring to the last Appendix. Experience using the first edition indicates that an individual's comprehension of the various quantitative methods is improved immeasurably by working through and understanding the solutions to the problems. Also, several of the problems can be solved by the computer, either in a batch-processing or a time-sharing mode.

I am indebted to various people who helped in this endeavor, particularly the many users of the first edition. I am deeply grateful to Professors A. Eugene Abrassart, Oregon State University; Myron K. Cox, Wright State University; Adolf Diegel, University of South Alabama; Weechet Ganjanaket, Texas Southern University; James Hershauer, Arizona State University; Arthur Kraft, Ohio University; Ross Lanser, San Jose State University; Wesley D. Ratcliff, Texas Southern University, and Bernard Shapiro, Lowell Technological Institute, for their helpful suggestions. In addition, I thank my former

professor, Professor James A. Black, of The Ohio State University (currently at Miami University) who was instrumental in formulating my ideas for the first and second editions. I congratulate Professors Virgil Carter (Cincinnati Bengals), Vincent Caruso, Michael Dreskin, Albert Klee, William Lewis, and J. Michael Thierauf at Xavier University for their constructive criticism. I am eternally indebted to Professor Robert C. Klekamp for his helpful suggestions and contributions in the revised edition. For his herculean efforts, he is welcomed as a coauthor, replacing Professor Richard A. Grosse who passed away in 1970. Finally, I thank the following graduate students for their contributions to the revised manuscript: James Blaser, Kerry Buck, David Colson, John Commons, Harold Fogg, Robert Harrison, David Huiett, John Iannone, Eugene Koehl, William Laib, Samuel Leary, Thomas Maxwell, Jerell McCullough, Robert McCall, Patrick McGuire, Daniel Milne, William Murphy, Elmo Rose, Andrew Rucker, Woody Scoutten, Floyd Soule, Michael Taggert, Arthur Thornton, and Gerald Witt. These students represent many disciplines found in business, resulting in an interdisciplinary-reading and problem-solving committee.

Robert J. Thierauf
December, 1974

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Overview of Operations Research

Chapter ONE

Operations Research– An Introduction

Today, management operates in a dynamic business environment that is subject to a bewildering number of changes. Many of these changes can be initiated by the manager, but usually they are not. They are dictated by shortened product life cycles and technological advances. Similarly, governmental and social environments are important change factors since the firm is strongly affected by an awareness of social consequences in its pursuit of profits. In view of these facts, today's efficient firm must rely heavily on quantitative methods and computers to handle its many routine and complex well-structured problems. This releases management to deal with the increasing load of poorly structured (nonprogrammable) problems that confront it. Thus management needs considerable computer assistance when employing mathematical business models to cope with the greatly increased complexity of its job.

Management has at its disposal several approaches in interpreting, analyzing, and solving business problems. Generally, the complexity of the problem indicates the appropriate method of analysis. The conventional approach follows past techniques and solutions. This method, being so static, offers little or nothing to the advancement of management since it is in opposition to the dynamics of business. A second approach, the observational approach, is the method of watching and learning from other managers in similar situations. It, too, is poor but improvements can be applied on occasion to improve a particular technique. Another approach to the solution of business problems is the systematic approach. This utilizes the concept of theoretical systems which may be somewhat different from the actual problem under study. Systematic approximation can be useful in obtaining a final solution since it utilizes a combination of approaches, in particular, the scientific method. Even though scientific management was aimed initially at manufacturing activities, its basic methodology can be applied to most current and future business problems.

History of Scientific Management

The exact origin of the scientic method is not known. Individual cases that have used the fundamentals of the scientific method have been found in writings thousands of years old. Moses' father-in-law, Jethro, is given credit for a treatise on organization principles in the Old Testament. Of more recent origin is the nineteenth-century work of Charles Babbage, *On the Economy of Machinery and Manufactures.*

Frederick Winslow Taylor, an American engineer, has been bestowed

the title "Father of Scientific Management." His process of investigation was essentially based upon an analysis of the duties and tasks of shop foremen. His scientific management was concerned with first line managers who should know the jobs of their men and then follow through to see that the jobs are performed in the best and most economical way. Taylor was concerned with the efficiency of the shop. He directed his attention to finding out how much one man could produce in one day through experimentation and not just subjective evaluation. As a result, he discovered some men were capable of doing an efficient job while others were not. He found some of the inefficient ones were more efficient in other jobs. Thus the idea of worker selection and training was defined. He established standards for workers and utilized specialization in manufacturing. In effect, Taylor applied scientific analysis to manufacturing problems; his techniques could be classified as an early form of operations research. His recommendations for scientic management can be set forth as follows:

1. Management must use the scientific rather than the rule-of-thumb approach.
2. Harmonious organization is obtained by assigning the appropriate man to each set of operations.
3. Cooperation between labor and management personnel must be achieved.
4. The best means of economical production has to be chosen.
5. Specialization of workers has to be obtained with the aim of increasing efficiency in production.
6. A striving for enterprise and individual prosperity must be accomplished.[1]

Henry L. Gantt, an associate of Taylor in the early scientific management era, is best known for his work in production scheduling. Prior to his time, bottlenecks were somewhat ignored. Gantt mapped each job from machine to machine in order to allow for and minimize every production delay. If machine loadings were planned months in advance by using the Gantt procedure, it was possible to quote delivery dates much more accurately. In addition, he contributed greatly to the scientific approach by considering the human aspect of management's attitude toward labor. The personnel department was recommended by Gantt as an integral part of Taylor's scientific approach.

The studies made by Taylor and Gantt were further advanced by the contributions of Frank B. and Lillian E. Gilbreth in the 1910s. Motion study, as a scientific approach, came into being. This consisted of dividing work into the most fundamental elements possible, studying these elements separately and in a relationship to one another, and using these studied ele-

[1] F. W. Taylor, *Principles of Scientific Management*, New York: Harper & Bros., 1910, p. 140.

[2] F. B. Gilbreth and L. E. Gilbreth, *Applied Motion Study*, New York: The Macmillan Company, 1917.

ments for building methods of least waste.[2] While Frank Gilbreth's studies were mostly related to production, Lillian Gilbreth's studies were concerned with the psychological point of view. The Gilbreths' contribution to scientific management complemented Taylor's time study.

Summarizing the 1910s in the United States, Taylor was interested in finding the one best way to accomplish a single task in a manufacturing process. The Gilbreths directed their efforts toward eliminating the wastefulness from unnecessary and inefficient motion in a particular task while Gantt looked at the manufacturing process from an overall point of view. Around the same time in Europe, a French engineer by the name of Henry Joseph Fayol published a book, *Administration Industrielle et Générale*, which dealt with the principles of general management. Fayol primarily studied the upper echelons of the firm from the higher levels to the lower levels. This is in contrast with Taylor who was concerned with studying the lower levels of the organization. Fayol's work is considered to complement Taylor's studies; that is, not only did they study opposite levels of the organization, but they also applied the scientific approach to the analysis of business problems. Taylor, Gantt, the Gilbreths, and Fayol all made significant contributions to scientific management by utilizing the scientific method for determining what should be accomplished under the existing conditions.

History of Operations Research

It is difficult to mark the official beginning of operations research. Many early pioneers, like those just mentioned, were performing work that today would be considered operations research. As early as 1914, F. W. Lanchester, in England, published papers on the theoretical relationships between victory and superiority in manpower and firepower. In the United States, Thomas Edison, as early as World War I, was given the task of finding the maneuvers of merchant ships that would be most effective in minimizing shipping losses to enemy submarines. Instead of risking ships in actual war conditions, he made use of a "tactical game board" for a solution. Around the same time (late 1910s), a Danish engineer, A. K. Erlang of the Copenhagen Telephone Company, was performing experiments involving the fluctuation of demand for telephone facilities upon automatic dialing equipment. His work is the foundation for many mathematical models used in waiting line theory today.

In the 1930s, Horace C. Levenson applied sophisticated mathematical models to large amounts of data which would otherwise have been totally unmanageable. One of his most interesting and best known studies involved customers refusing to accept C.O.D. packages from a relatively small order house. The rejection rate was about 30 percent of gross sales. Two causes of rejection were isolated: first, more expensive orders were more frequently refused; and second, merchandise shipped later than five days after the order was placed. On the average, orders older than five days were not profitable. With such data available, it was relatively easy for the mail order