SCIENTIFIC INVENTORY MANAGEMENT

Buchan and Koenigsberg

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FOREWORD

Inventory management is a topic of considerable and widespread interest. In this book the authors have concentrated on the application of scientific techniques to the solution of a variety of inventory management problems. Broadly speaking, the inventory management problem is one of maintaining, for a given financial investment, an adequate supply of something in order to meet an expected distribution or pattern of demand. The word "something" is used advisedly here. To manufacturing management, the word inventory immediately connotes finished goods inventories — the stocks of the company's end product available for distribution or sale to the company's customers. If pressed, managers will include in-process inventories of partly-finished products moving through the production or assembly stages and inventories of parts and raw material to be incorporated in the end product. In a broader sense, however, the term inventories includes machines, machine parts, tools and even personnel, trucks, cash, and auxiliary equipment of all kinds required to run a business. In non-manufacturing organizations, evaluation of other things might also be considered as inventories — a library's inventory of books, a bank's inventory of money, a consulting organization's inventory of specialists' skills.

To a surprising degree, many of these seemingly quite different problems have a great deal in common when formulated mathematically. In many cases, when the physical characteristics of the inventory and the procedural details of managing it are isolated, both the demand and supplying it fall into recognizable statistical patterns. Within this framework, one may talk about the cost of maintaining inventory or the cost of replenishing inventory, to serve particular policy objectives. One may put together the costs of acquiring inventory, holding it, and failing to supply consumers in order to arrive at inventory policies which will minimize the total of these costs or maximize profits.

During the last thirty years, but particularly in the last ten years, considerable analytical knowledge about problems of this general classification has been developed, as has wide experience in a variety of actual inventory situations. Special techniques, such as queuing theory and linear programming, have proved helpful in solving a number of problems that arise in the general inventory management area. Using a computer to stimulate actual business operations provides a means for predicting the inventory and customer service levels to be expected under varying conditions and, therefore, gives a quantitative basis for selecting particular inventory management policies.

This is one management problem area to which much scientific attention has been given and to which a considerable amount of management effort has been applied. The authors have referred to literature on the theory as well as its application to the inventory problem. They have compiled for the interested technician an extensive collection of modern inventory models in sufficient mathematical detail to permit their evaluation and utilization without repetition of mathematical derivations available in the literature. In a sense, however, the book is directed more toward the non-technician—toward solution of the practical problems of using inventory management theories in actual business situations and description of the pitfalls, costs, and benefits of such use.

Much of the book is devoted to examining the problems encountered with existing techniques in managing particular inventories and to illustrating the design, installation, control, and updating of a more effective system that is not unnecessarily complex. One could look at almost any complicated inventory problem and say that substantial improvements are certainly possible in the inventory turnover and in the utilization of investment and contribution to profits. But what about the cost and complexity of designing, operating, and controlling the system? As systems change, what costs will result and what will be the financial return to the corporation from the utilization of modern inventory management theory?

In this book the authors have attempted, through the use of case histories, to explore these questions in depth. They illustrate ways to determine implied costs and use simple nomographs and tables which aid in the efficient and inexpensive solution of numerous practical problems. Efforts to detail the net effect of the installation of a scientifically based inventory management system on the profit of a corporation are also included. It should be pointed out that the full impact of such an inventory management system may not be felt for many months, or even years. This is particularly true in the retail field where the utilization of scientific techniques is a drastic change from the common methods which have been used for generations by merchants. To appreciate what scientists and analytical techniques can add to

these merchants' years of experience, one must think of the thousands, and in some cases hundreds of thousands, of decisions being made in a merchandising organization each year.

These decisions must often be made by clerical personnel who are unaware of the effect of individual inventory decisions on costs and customer service. They, therefore, can only carry out formal instructions or informally attempt to make each decision based on intuition and experience. Yet it is the aggregate of all these judgements which provides the over-all return on investment and customer service level. Now, the expected aggregate results for various systems — results equivalent to many years of actual experience — are readily available through mathematical analysis and manual and computer simulation. Based on these evaluations, inventory systems can be designed and built into the day-to-day operation of a store, bank, or manufacturing company so that the multitude of individual inventory decisions will be made consistently.

Nevertheless, these scientific techniques are strictly aids to management. They cannot replace the judgement and intellect of the individual who may have to modify and improvise to deal with the unexpected. The techniques, in combination with the manager's judgment, can provide a system superior to that produced by the separate use of either.

With the advent of electronic computers and the tremendous strides taken during the past five years in the development of smaller, more economical, and more efficient data processing systems, it becomes increasingly apparent that the inventory management problem can be solved in many more companies by the use of scientifically based techniques. Scientific systems can be incorporated into the normal business operations of a company so as to enhance the achievement of the company's basic objectives. It is the primary purpose of this book to report on actual uses along these lines, as well as to illustrate how the underlying theory of scientific inventory management can be applied to a variety of industries and types of applications.

It might be well here to preview briefly the organization of this book, which is divided into two sections. The first 15 chapters may be considered the application section since they basically concern case studies of actual inventory problems in a variety of industries. The last 10 chapters may be termed the theory section because they primarily discuss the mathematics of scientific techniques or families of techniques.

The application section begins with an introductory chapter designed to explain to the layman the underlying logic of the basic inventory formulae and closes with a chapter on the preparation and use of the nomographs for routine clerical solution of such formulae. The intervening chapters present 13 inventory management case studies. Each of these chapters is

designed to be self-contained in that the particular case can be understood from the reading of a single chapter, and usually the problem and the results (or at least the expected results) are described early in the chapter. There is, however, an over-all pattern of organization which will reward the lay reader who digests the case study material in the order presented. The first chapter explains the various inventory models or systems which are used in the applications section, while the following chapters are arranged in increasing order of complexity as to both the type of inventory problem handled and the techniques used. Chapter 2 deals with simple retail inventories of items for which the demand is fairly stable and to which the manual application of the classic inventory reorder point and replenishment level formulae are both straightforward and practical. The proper allocation of inventory control effort via stratification or classification of inventory items is first demonstrated here although it is similar for a variety of industries as shown in subsequent chapters.

The next chapter shows how the use of a replenishment level system can be modified to incorporate a reorder quantity (the so called optional replenishment system) and how this is useful for managing supermarket warehouse inventories where there is an additional complexity of car load order quantity restrictions. Chapter 4 shows the use of reorder point formulae for wholesale drug inventories with item order quantity restrictions.

As the chapters proceed toward more complex manufacturing inventories, other considerations are introduced. Multiple reorder points for widely fluctuating demand are shown in Chapter 6. The effect of varying numbers of issues of different issue quantities is considered in Chapter 8; handling of seasonal and calendar variations in sales, along with order quantity limits imposed by the production process, is presented in Chapter 9; the allocation of inventory among decentralized locations is shown in Chapter 10; and exponentially smoothed forecasts of usage are utilized in Chapter 13. The existence of three common statistical distributions of demand, Poisson, exponential and normal, and the use of these distributions is illustrated in Chapters 2, 6 and 7.

In addition to actual application of the common scientific inventory formulae, other possibilities for improved inventory management are demonstrated, including a simple numerical method for controlling an "inventory of cash" in Chapter 5, and adaption of the common retail "open-to-buy" controls for use in a "crash program" for reducing manufacturing inventories in Chapter 14. One particular source of improvement, the computer system, is discussed at length because of its great impact on business control systems generally and inventory management in particular. The importance of the computer in enabling rapid, accurate routine application of scientific inventory formulae is demonstrated for the supermarket inventories of

Chapter 3 and the complex manufacturing inventories of Chapters 10 and 13. Chapters 11 and 12 are included, however, to show how the computer can be used for better inventory control even without scientific reorder formulae. The computer greatly speeds up the existing data processing, consequently increasing the ability to adjust to schedule changes and decreasing the risk of obsolescence and lost sales. In order to communicate this effectively, a number of details of data processing and computer operation are presented, since these are the essence of a computer installation. Incidentally, it is perhaps unfortunate that the computers included in these cases are all produced by one manufacturer, but the simple fact is that this manufacturer's machines accounted for about two-thirds of the business computer installations in recent years.

The second section of the book begins in Chapter 16 with a summary of the philosophy underlying the installation of working inventory management systems and an enumeration of the relevant costs. Chapter 17 considers a simple "static" inventory model for the inventory problem in which only a single purchase order can be placed and the costs of unsalable items are balanced against the cost of lost sales. Chapter 18 introduces "dynamic" models for the more common inventory reorder problem, beginning with the classic Wilson Economic Order Quantity formula and incorporating the effect of capital restrictions and price breaks in the models. The discussion of dynamic models is expanded in Chapters 19 and 20 with explicit treatment of statistical demand distributions, reorder points, buffer stocks, and service levels, followed by a comparison of the Wilson, replenishment, and optional replenishment policies, and an evaluation of the multiple reorder policy.

Chapter 21 illustrates the application of the Queuing Theory to some inventory queue problems. This presentation is elaborated in the next chapter to show the use of this technique on in-process inventories. The mathematical description of multi-stage inventories in Chapter 23 explains the effect of various demand impulses as they pass through a product distribution system from retail to production inventory stages. Chapter 24 introduces the use of another common operation research tool, linear programming, for the solution of certain inventory problems and the last chapter carries this forward into the area of non-linear programming.

In summary, the book reports on the actual use of a number of scientific inventory management techniques in a variety of industries, concentrating particularly on the organizational and procedural problems which consume the vast bulk of the installation effort when converting abstract inventory theories into working inventory management systems. It also contains a fairly comprehensive resume of the mathematical techniques which are applicable to the broad area of business inventory management.

Many members of the firm Touche, Ross, Bailey & Smart have contributed toward the preparation of this book. Of course, the outstanding contributors are the authors, Dr. Ernest Koenigsberg, who did all of the writing in the theory section, and Mr. Joseph F. Buchan, who did most of the editing and much of the original writing in the applications section. Both authors, of course, reviewed and edited the entire manuscript and received invaluable assistance in this from Mrs. Susan Koenigsberg.

Credit is also due to Nicholas Radell, David Fleisher, Dr. George O'Brien, James Bresnahan, Dr. Gordon Davis, Richard Davis, Dennis Price, Dr. Dennis Mulvihill, Sanford Ackerman and Alvin Wanthal Jr., who did the actual work on various cases described in the application section, and who, in most instances, wrote the original drafts of the chapters on which their names appear. Mr. Buchan, however, did all of the writing on Chapters 7 and 13 as well as the bulk of the writing on Chapters 2, 6, and 12, and is of course responsible for the final version of all the application chapters. Credit should also go to Richard Trueman who assisted Dr. Koenigsberg in the preparation of Chapter 24.

No foreword to this book would be complete without recognizing here the great support of the senior partners of the firm who have seen it through to the conclusion of the writing and its clearance for publication. Particular credit is due to Mr. John W. McEachren, Managing Partner of Touche, Ross, Bailey & Smart, for his counsel on business matters and for his continued strong support in this endeavor.

ROGER R. CRANE

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CONTENTS

chapter one

INTRODUCTION TO SCIENTIFIC INVENTORY MANAGEMENT

This chapter is intended to provide a basic understanding of scientific inventory management, what it is and why it works. The fundamental concepts are illustrated by the introduction of several, but not all, the various inventory models which have proved useful in practice. The chapter is directed to the reader who has no previous experience with the subject and no extensive background in mathematics.

Those already familiar with inventory theory may wish to skim the presentation in this chapter, noting the references to business practices, or they may wish to skip to the following chapters, which treat the practical problems of converting inventory theory into working inventory systems for a variety of businesses. The newcomer to inventory theory, however, should master the concepts presented in this chapter so that he may fully understand their adaptation to the specific problems presented in the following chapters.

It is particularly important to understand the concept of "making a

model" of the operation, because this is fundamental, not only to scientific inventory management work, but to all applications of Operations Research techniques to business problems. In this context, a *model* is a representation of the behavior of an actual business operation, and an inventory model can be described by a number of related equations. If the model is an adequate representation of the operation, we shall see that it is often possible to learn how to improve the operation by experimenting with the model.

A BASIC INVENTORY MODEL

The logical starting point for a discussion of scientific inventory management is a basic inventory model which, though quite simple, has proved widely useful. The model itself is somewhat of a classic, having first appeared in the literature more than thirty years ago,[1] and it illustrates effectively the typical assumptions and simplifications involved in building a model of a business operation. This basic model is the "fixed order quantity system," frequently referred to as the *Wilson formulation*. In this system, the inventory reorder quantity is fixed, and a reorder is placed for this quantity whenever the inventory on hand drops to a particular level, referred to as the *reorder point*. A somewhat different model will be introduced later, the so-called replenishment system in which the reorder date is fixed and the reorder quantity varies according to the inventory on hand (see Exhibit 1–18).

The typical operation of the fixed reorder quantity model is illustrated in Exhibit 1–6, after the concepts which underlie the use of this model have been presented. The development begins with a discussion of the costs of managing an item of inventory and the use of these costs in determining the fixed order quantity for that item and continues with a discussion of the method for determining when to place the reorder.

THE ECONOMIC ORDER QUANTITY (HOW MUCH TO REORDER)

The fixed order quantity system is based on selecting that order quantity which will minimize the total variable costs of managing inventory. In determining this "economic order quantity," the model assumes that the cost of managing inventory is made up solely of two parts: ordering cost and carrying cost.

Ordering cost is the additional cost of placing an order, a cost which is considered to be independent of the size of the order. In manufacturing, this might include set-up costs: in retailing, it would be limited to the costs incurred in processing a purchase order. If C_o is the cost of placing an order and q is the order quantity, the *unit* cost of placing an order is C_o/q, and this de-

[1] R. H. Wilson, *Harvard Business Review*, 13, No. 1 (1929) 116–28. See also F. E. Clark, *Harvard Business Review*, 6 (1927–28) 394–400; H. N. McGill, *Industrial Management*, 73, No. 6 (1927) 344–47; R. C. Davis, *Manufacturing Industries*, 9, No. 4 (1925) 353–56; G. F. Mellen, *Management and Administration*, 10, No. 3 (1928) 155; H. S. Owen, *Industrial Management*, 70, 71 (1925, 1926) 9 installments; G. Pennington, *Manufacturing Industries*, 13, No. 3 (1927) 199–203; R. H. Wilcox and W. A. Mueller, *Harvard Business Review*, 5 (1926–27) 197–205.