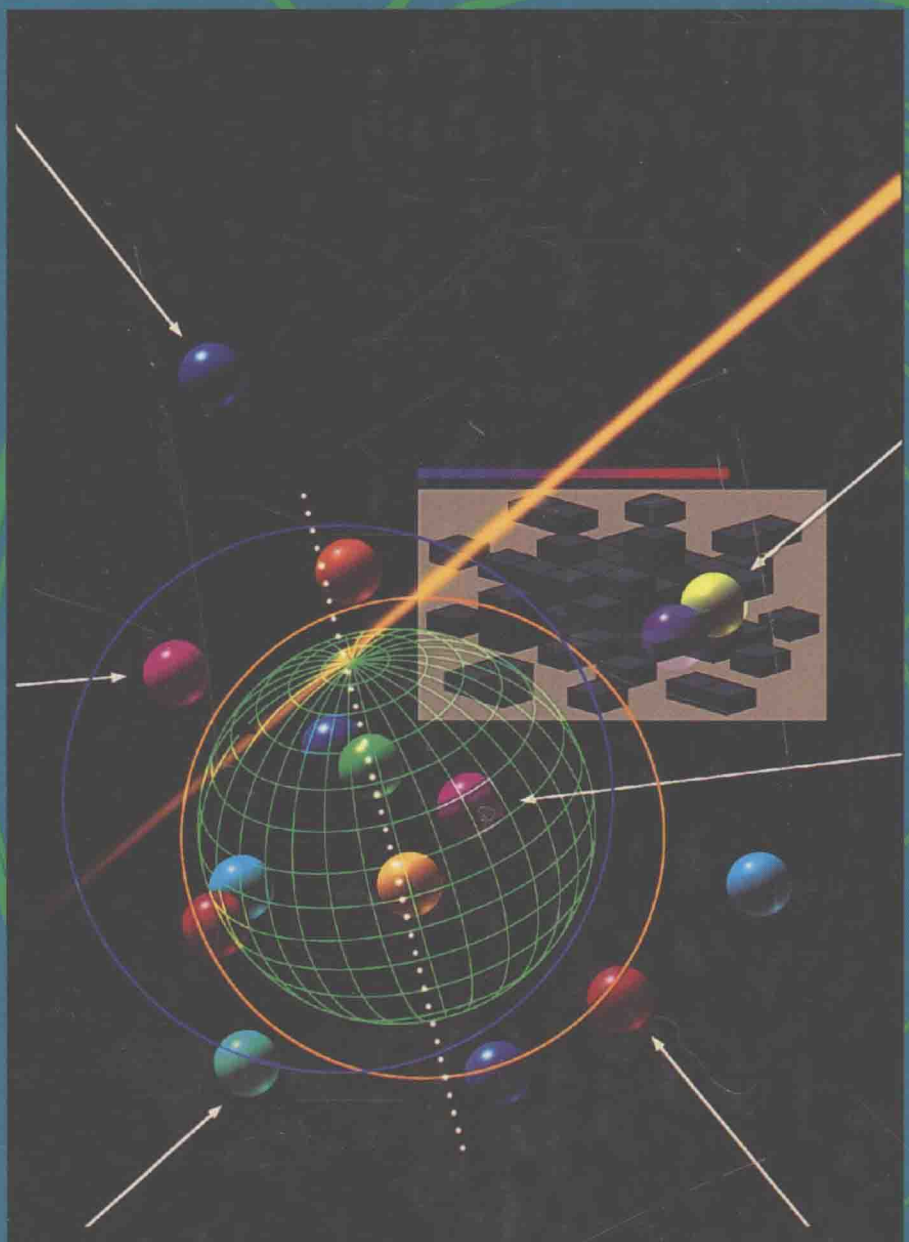
PRODUCTION/OPERATIONS MANAGEMENT

FIFTH EDITION



ROGER W. SCHMENNER

PRODUCTION/OPERATIONS MANAGEMENT

From the Inside Out

Fifth Edition

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To my father, a helluva operations manager

PREFACE

The reception that this book has received in all four of its previous editions has been very gratifying. With this fifth edition, I have once again had the opportunity to approach anew the original vision that I had for the book. I saw it as unifying the best elements of two schools of thought about production/operations management (POM): one anchored in the application of various techniques to POM problems; the other anchored in the dilemmas and decision making of the operating manager. With this edition, I am closer to that original vision.

The fifth edition has undergone a major overhaul. A recounting of the changes is instructive:

1. *Reorganization.* The plant and service tours that formerly began this text are now positioned at the back. Furthermore, the text has been rewritten so that references to the Tours do not presuppose the student having read even one of them. This restructuring of the book thus gives instructors the leeway to assign whatever topics they may want, and in whatever order that makes sense to them. Although I recommend the order I have chosen for the material, the use of the book no longer depends on that order.

   Where there used to be thirteen chapters in addition to the Tours, there are now fifteen, with some of the longer chapters split into more digestible pieces. This revamping of the material has particularly helped the exposition of some of the more traditional topics, such as production planning, inventory control, queuing, and shop floor control. Some chapters even carry different names now.

2. *Theme.* The ordering of the material and the point of view stress the learning of operations management from a bottoms up, inside out approach. This stress is so consistent that the book has been retitled *Production/Operations Management: From the Inside Out* to underscore it.

2. *Summaries.* Key ideas and tools introduced in the text are recapitulated at the end of each chapter. These recaps also highlight the distinctive features of world-class operations.

4. *Fresh Material.* Considerable amounts of fresh and up-to-date material have been added to this fifth edition. There is a new first chapter that introduces the book and that discusses key aspects of different manufacturing and service processes. Chapters 2 and 3, dealing with flows, bottlenecks, balance (including line balance), queuing, and layout, have been thoroughly revamped. Chapter 4, on quality, has likewise undergone substantial change and rewriting.

   A thorough-going revision has been applied to Chapters 6 through 10 – those dealing with the important and traditional topics

of production planning, scheduling, inventory management, MRP, purchasing, logistics, shop floor control, and project management. This material is now more easily assimilated, and the coverage is more complete as well.

Additional material has been added to the chapter on just-in-time manufacturing and to the chapter on technology and design. In fact, the revisions to the latter necessitated a retitling of that chapter.

In all of the other chapters, small but helpful changes have been made throughout, making the text both more readable, and in particular places, more quantitatively rigorous.

5. *Updated Plant and Service Tours.* All of the plant and service tours except one (Thalhimers) have been brought up-to-date as of the summer and fall of 1991. There is a new tour of the General Motors plant in Oklahoma City, currently GM's best-performing domestic plant. There is also a brand new tour of a **project** (Geupel DeMars), which does a better job than ever before to describe what project management entails in practice.

ACKNOWLEDGMENTS

This edition, as with the previous ones, has benefited greatly from the cooperation I have received from a number of companies. Although I cannot acknowledge the contributions of everyone in those companies, I would like to mention a few persons who were especially helpful with this edition: James Grippe of International Paper; Joseph and Lillian Gehret of Norcen Industries; Edward Jecelin of Jos. A. Bank Clothiers; Thomas Desser, Michael Williamson, and colleagues at General Motors (C-P-C Group—Oklahoma City); Alicia Hayes and Larry Levensky of Burger King; Al Sanfilippo of Stroh Brewery; Gregg Hutchinson of Ogle-Tucker Buick; Frank Jonas of Arthur Andersen & Co.,; David Moffitt of Geupel DeMars; Kenneth Good of Black & Decker; James Krejci of Navistar International; and Frank Coyne and Victor Baldridge. My sincere thanks to them and to their colleagues.

In addition, I would like to acknowledge the helpful comments and suggestions of the following reviewers for the fifth edition: Douglas Elvers, University of North Carolina, Chapel Hill; Phillip Carter, Michigan State University; Daniel E. Shimshak, University of Massachusetts, Boston; Susan W. Engelkemeyer, Babson College; Ernest Koenigeberg, University of California, Berkeley; James Fitzsimmons, University of Texas, Austin.

Some of the problems and situations for study from the earlier editions of this book are the work of Joseph R. Biggs and Thomas F. Callarman. They reduced the burden for me at an important time in this book's early development.

Linda Baker and Cynthia Panettieri helped me prepare aspects of the manuscript for this edition, and Margaret Noble tracked down numerous bibliographic references for me.

My wife, Barbie, and my children, Will and Andrew, were again most forgiving of my attachment to this book. I apologize for all the time I spent with it that I could have spent with them. I owe them much and hope that someday they may even read what all the fuss was about.

Roger W. Schmenner

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CHAPTER 1

THE SPECTRUM OF MANUFACTURING AND SERVICE

Operations. For many people, mentioning the word brings on a rush of disagreeable feelings and sensations. Details. Pressure. Long hours. Inhospitable working conditions. Dull colleagues. For these people, a company's operating managers—usually typed as engineers who could not hack it in the "more creative" design aspects of the business—lead very unromantic careers. Moreover, operations is viewed as a dead-end job with no future in the upper layers of management.

This description is an exaggeration, of course, but it conveys some of the impressions that people hold about operations. This text is a crusade against that kind of stereotype of the operations manager. In fact, operations offers an exciting and dynamic management challenge that is as absorbing and rewarding as any marketing or finance can offer. A badly run operation can be a staggering drain on corporate profits and morale, as a number of even large corporations can attest; conversely, a well-run operation can be a competitive weapon every bit as potent as any in the corporate arsenal.

For many senior managers, the path to the top snaked through operations—even for those whose climb has been in so-called "marketing companies." Many others would admit that a tour of duty in operations was an important part of their general management education and background. The point is that operations is and rightly should be a key concern for most companies and one that all students of business who aspire to general management responsibilities ought to know about.

The importance of operations has been highlighted in recent years. Numerous articles have appeared in business periodicals stressing the need for young managers, especially those fresh from business schools, to seek out careers in operations jobs. The success of the Japanese has reinforced this view in many people's eyes, since the prowess of the Japanese is widely recognized to be in manufacturing.

Our standard of living today owes much to our forebears' ability to create wealth. Fortunately for us, because of their efforts, we have become better and better at transforming raw materials of all sorts into useful, high-quality products. So, too, have we become better at delivering an ever-expanding menu of services to both businesses and final consumers. We have, over the years, become increasingly efficient at these tasks—wasting fewer resources, satisfying customers more completely, requiring less physical exertion from ourselves, and frequently,

although not always, being kinder to the environment in the process.

These are triumphs of the operations management function within the manufacturing and service businesses of our economy. Our productivity gains, as measured by history's trace of real (inflation-adjusted) per capita income, have snowballed. We have more equipment to work with than ever before; better, more capable equipment, but also better methods and more informed ideas about what it takes to produce effectively goods and services that are valued by customers. This triumph, of course, is a shared one. Product engineering, marketing, sales, and other company functions are, in part, responsible. Nevertheless, the manufacturing or service operation itself has been in the thick of the productivity advance whose fruits we enjoy today.

THE OPERATIONS FUNCTION

Although somewhat "invisible" to the marketplace, the operations function in a typical company accounts for well over half the employment and well over half the physical assets. That, in itself, makes the operations function important. In a company's organization chart, operations often enjoys parity with the other major business functions: marketing, sales, product engineering, finance, control (accounting), and human resources (personnel, labor relations). Sometimes, the operations function is organized as a single entity which stretches out across the entire company, but more often it is embedded in the distinct, typically product-defined divisions into which most major companies are organized.

In many service businesses, the operations function is typically more visible. Service businesses are often organized into many branches, often with geographic responsibilities—field offices, retail outlets. In such tiers of the organization, operations are paramount.

The operations function itself is often divided into two major groupings of tasks: line management and support services. Line management generally refers to those managers directly concerned with the manufacture of the product or the delivery of the service. They are the ones who are typically close enough to the product or service that they can "touch" it. Line management supervises the hourly, blue-collar workforce. In a manufacturing company, line management frequently extends to the stockroom (where materials, parts, and semi-finished products—termed "work-in-process" inventory—are stored), materials handling, the tool room, maintenance, the warehouse (where finished goods are stored), and distribution, as well as the so-called "factory floor." In a service operation, what is considered line management can broaden considerably. Often, order-taking roles, in addition to order-filling roles, are supervised by service line managers.

Support services for line management's operations can be numerous. Within a manufacturing environment, support services carry titles such as quality control, production planning and scheduling, purchasing, inventory control, production control (which determines the status of jobs in the factory and what to do about jobs that may have fallen behind schedule), industrial engineering (which is work methods-oriented), manufacturing engineering (which is hardware-oriented), on-going product engineering, and field service. In a service environment, some of the same roles are played but sometimes under vastly different names.

Thus, the managers for whom operational issues are central can hold a variety of titles. In manufacturing, the titles can range from vice-president—manufacturing, works manager, plant manager, and similar titles at the top of the hierarchy, through such titles as manufac-

turing or production manager, general superintendent, department manager, materials manager, director of quality control, and down to general foreman or foreman. Within service businesses, "operations manager" is sometimes used but frequently the title is more general—business manager, branch manager, retail manager, and so on.

OPERATIONS: FROM THE INSIDE OUT

The title of this textbook, *Production/Operations Management: From the Inside Out*, highlights a theme that pervades the structure and philosophy of this book. Most managers, as they grow in their jobs, learn about their production processes from the bottom up. The decisions they take start with small scale, incremental improvements to existing processes. Only as those managers rise in the ranks do they then become involved in larger, more costly, more long-term, and more strategic decisions. That is, first they master their processes and then they learn how to make an ever-widening circle of decisions about them. Their appreciation for and knowledge of operations management grows *from the inside out*.

This is a natural way to learn about operations. Before one can plan, execute, or control anything about an operation, one must learn about it and how to improve it bit by bit. Similarly, if one were brought into a troubled company and asked to turn it around, one would have to start with the simple, incremental improvements before there would be the cash or vision to change the company in major, strategic ways. One starts *from the inside and works out*.

If you have seen one factory, you certainly have *not* seen them all. The same holds true for service operations. Manufacturing and service processes are wonderfully diverse. For the manufacturer, not only do machinery and product engineering differ, but also the ways in which the factory is organized and run. Similar diversity prevails in services, which can differ markedly—hospitals versus grocery stores versus bank check clearing houses versus interior decorators.

This book begins with an overview of various kinds of manufacturing and service processes. Moreover, the entire last segment of this book describes, in some detail, a collection of ten very distinct manufacturing and service operations that provide an in-depth appreciation for "process." These various tours can serve as useful groundings in the character of different operations and can be used to illustrate any number of the concepts and techniques that comprise the study of operations management. While the use of this text does not require reading these tours, and certainly not all of them, you may well want to examine at least a few of them to get an "armchair" taste of the factory or service operation to anchor your appreciation for what follows in this text.

Once the various processes are discussed, the text proceeds to examine existing operations and how to improve them. The issues dealt with are the basic building blocks of good operations decisions: analysis of materials and information flows, breaking bottlenecks, achieving balance, ameliorating quality, improving methods, empowering people, planning production, scheduling it, controlling production and inventories, and more.

Only when these basic concepts are discussed does the text proceed to the larger, more strategic issues of adding capacity, taking advantage of technology, introducing new products, restructuring supply relationships, and devising an operations strategy.

With this background on this text's structure and philosophy, let us proceed to examine the diversity of both manufacturing and service operations and the kinds of decisions that can be made concerning them.

PART ONE

MANUFACTURING The Spectrum of Manufacturing Processes

The factory tours in the back of this text describe a rich diversity of technologies and approaches to a variety of the issues faced by manufacturing managers. The summary chapter at the conclusion of the tours compares and contrasts the processes in considerable detail. Suffice it here to present a much more "bare bones" discussion of five major types of manufacturing processes that one can engage in. They form a spectrum (see Figure 1-1).

1. *The Project.* The project—building a skyscraper, bringing a new product out of the R & D labs, making a movie—is sometimes excluded from consideration as a manufacturing process because, by its nature, it exists only to do a particular, unique job. This is not to say, however, that one project may not look very similar to another. Many projects, be they large buildings, new products, or movies, require much the same work to get them up and running. There are certain regularities present in a project, among them:
   - Projects typically make heavy use of certain skills and capabilities at particular times and little or no use of those skills at other times.
   - Projects can often usefully be seen as the coordination of part-time or subcontracted skills and capabilities (people, equipment, etc.). Skills and capabilities, of course, can be many and varied.
   - The coordination of those skills and capabilities requires a lot of attention to planning and scheduling, and subsequently, attention to the control of that schedule, and any rescheduling or expediting that may be required. Great attention must be given to which tasks must be accomplished before others (a precedence diagram) and what the expected durations for those tasks are.
   - The quality of any project depends greatly on the skills and care of the members of the project team.
2. *The Continuous Flow Process.* At the other extreme of the process spectrum lies the continuous flow process. Many high volume consumer goods and commodities are made by continuous flow processes—oil refining, food processing, papermaking, lightbulb fabrication. The continuous flow process's most significant characteristic is how materials move through it—hardly ever stopping, moving constantly from one process operation to another. With a continu-

FIGURE 1-1 The Spectrum of Manufacturing Processes.

ous flow process, one can estimate realistically how long it takes to transform raw materials into a specific product. Work-in-process inventories exist at well-defined levels and are low relative to the value of output the continuous flow process generates. Capital investments and automation, on the other hand, are often higher than those of other processes, especially when contrasted with the workforce employed. Layouts are frequently product-specific, typically with a straight-line character to them, as the products in the making go from one operation to another.

Continuous flow processes can be very productive and very profitable, assuming normal sales levels. Only when sales levels plunge is the profitability of the continuous flow process in jeopardy.

3. *The Job Shop.* Lying next to the project in the process spectrum is the job shop. It is the most flexible process for creating a wide variety of products in significant quantities (the project, almost by definition, does not produce in quantity). Machine shops, tool and die shops, and many plastic molding operations are job shops, working to fulfill particular customer orders.

   The job shop layout is often distinctly different from that of a continuous flow process; it groups similar equipment together, primarily because no single product generates enough sales volume to justify the creation of a product-specific array of equipment.[a] Often a job shop has a diverse array of equipment and capabilities to choose from.

   The flow of material in a job shop can be complex and far from a straight line in character. Materials can be routed in many directions and can loop back to the same equipment later in the processing cycle. With each order (job) capable of such complexity, it is absolutely essential that information on how the order is to be routed through the factory, what is to be done to it at each step of the way, and how much time and effort is actually spent on it, follow the job. The job shop lives by its information flows. This information is vital, because job shops typically bid for work. Without good information on costs, times (run times, set up times, labor content times), routings, and process steps, a job shop would be seriously disadvantaged.

4. *The Batch Flow Process.* One step toward the continuous flow process from the job shop is the batch flow process. The job shop and the batch flow process have a good deal in common. Their layouts are similar, with equipment grouped by function rather than by product.[b] The product is regarded as moving from department to department within the factory. A batch flow operation depends on information such as routings and process steps and tracks costs and times spent. However, batch flow processes typically have a set menu of products that they produce, frequently, in set quantitities (lot sizes). The batch flow operation is thus somewhat more standardized than the job shop, particularly as it relates to routings and costs.

[a] As will be described later, sometimes families of parts or products can be identified and exist in enough volume to justify the creation of a manufacturing cell (sometimes called "group technology") within the job shop. Such a manufacturing cell gathers various, different pieces of equipment together in a product family-specific configuration.

[b] Here, again, the innovation of the manufacturing cell is applicable. Defining manufacturing cells for the batch flow process rather than the job shop is likely to be much easier to do because the identification of a family of parts is likely to be easier.

While the job shop usually operates to fulfill an outside customer's order by an agreed upon due date and in whatever quantity is ordered, the batch flow operation usually produces in established lot sizes that move into an inventory from which further production proceeds or customer orders are filled. Batch flow processes are commonplace, especially when one considers all the times "fabrication" must be done. Examples of batch flow processes include much of the chemical industry, semi-conductor fabrication, apparel, much of the steel industry, and huge chunks of the metal bending, metal forming, and metal machining industries.

5. *The Line Flow Process.* Between the batch flow and continuous flow processes, along the process spectrum, lies the line flow process. In reality it lies closer to the continuous flow process because it presents some substantive distinctions from the batch flow. The line flow process is most popularly exemplified by the moving assembly line that one finds in the auto industry, but it is also found in a host of other assembly industries such as consumer electronics and computers. In contrast to the batch flow process, the line flow process exhibits the following charactertistics:
   - A product-specific layout with different pieces of equipment placed in sequence ready to perform operations on the product. There are, of course, mixed model lines that can produce distinctly different models of the basic product, but the more diverse the products made, the less satisfactory the line becomes at producing those.
   - The product moves readily from one operation to another so that there is little work in process inventory, nor is there a stockroom in the product's path. This also means that there is a great need to examine the "balance" of the process so that the different tasks to be accomplished take roughly the same amount of time to perform and have the same capacities, not just over weeks of time, but over minutes of time.
   - The paperwork needs of the line flow process are less demanding than the batch flow. Routings are not needed and operations sheets can frequently be simplified, if not eliminated altogether. The need for tracking labor and machine inputs to particular products/parts also fades away.
   - In contrast to the continuous flow operation, the line flow is somewhat more flexible, and generally less automated and more labor intensive.

As one proceeds across the spectrum from project to continuous flow, one tends to move from a highly individualized, flexible process to one that is much more inflexible in the products it can make but, at the same time, much more productive and efficient in how it makes them.

Hybrid Processes

The five process types introduced above—project, job shop, batch flow, line flow, and continuous flow—are all "pure." Many factories are combinations of two (sometimes more) of these pure processes. Popular hybrids are the batch flow-line flow hybrid (auto engines, air conditioning, furniture) and the batch flow-continuous flow hybrid (breweries; many high-volume consumer products whose raw materials are made in batches, such as photographic film).

In these processes the first part of the flow of materials looks like a batch flow process (often, this part of the process is labelled "fabrication") while the latter part resembles a line or continuous flow process (and this part of the process is labelled "assembly" or "finishing").

Importantly, the two portions of the hybrid are separated by an inventory, typically termed a "decoupling" inventory. The batch flow process acts to fill up the inventory with parts or semi-finished product which then is drawn down by the line or continuous flow process for assembly or completion.

The reason the hybrid process is divided into two parts is that the batch flow process is not normally as nimble as the line flow or continuous flow process. The batch flow may not be as nimble because significant chunks of time may be needed to set up the existing machines for a different component of the finished product. This puts pressure on the batch flow process for longer runs than would be needed to match precisely the product mix and quantities produced by the line or continuous flow process, which normally can change over to other products more quickly. If the batch flow process tried to match the line or continuous flow process precisely (say, hourly or daily), it would lose a lot of time to setup and this downtime could rob the process of the capacity it needs to keep up with overall demand.[c] Thus, the batch flow process does not attempt a precise match of the line or continuous flow process's product mix and quantity, but rather a quantity and product mix match over a much longer period of time, say weeks or months. The batch flow process then acts to replenish the decoupling inventory, while the line or continuous flow process acts to fill particular customer orders.

MANUFACTURING CHOICES

Manufacturing managers are faced with a wide variety of choices, and how well they make those choices, in large part, determines how successful they and their companies are. These operations choices define, in essential ways, the study of operations management. The remainder of this book is devoted to exploring how these choices are made and how they can be made better. Three broad categories confront the manager: (1) technology and facilities, (2) operating policies, and (3) operations organization. Let us review these categories and choices in turn by noting a number of questions about them. These questions point to some of the alternatives managers face. Do not be discouraged if you do not know exactly what these questions refer to. The remainder of this book should clarify things for you. Rather, let these questions "wash over" you to give you a feel for what operations managers face.

Technology and Facilities

These choices frequently involve large capital expenditures and long periods of time. These are the big decisions that do much to define the type of process employed.

1. *Nature of the process flow.* Is the flow of product through the plant characterized as rigid, with every product treated in the same way? At the other extreme, is the flow a jumbled one, with products routed in many different ways through the factory? Or, does the flow of product through the process fall somewhere in between?
   - Are segments of the process tightly linked to one another, or are the connections between process segments loose? How quickly can materials flow through the process?
   - Is the process a "pure" one or is it a hybrid of different process types?
2. *Vertical integration.* How much of a product's value is a direct result of factory operations? Should production involve more (or

[c] Much of the push toward just-in-time manufacturing (JIT), discussed in Chapter 11, can be interpreted as a remedy for this deficiency of batch flow processes. In essence, JIT tries to make the batch flow process operate with the efficiency of the line flow process.