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OPERATIONS Management

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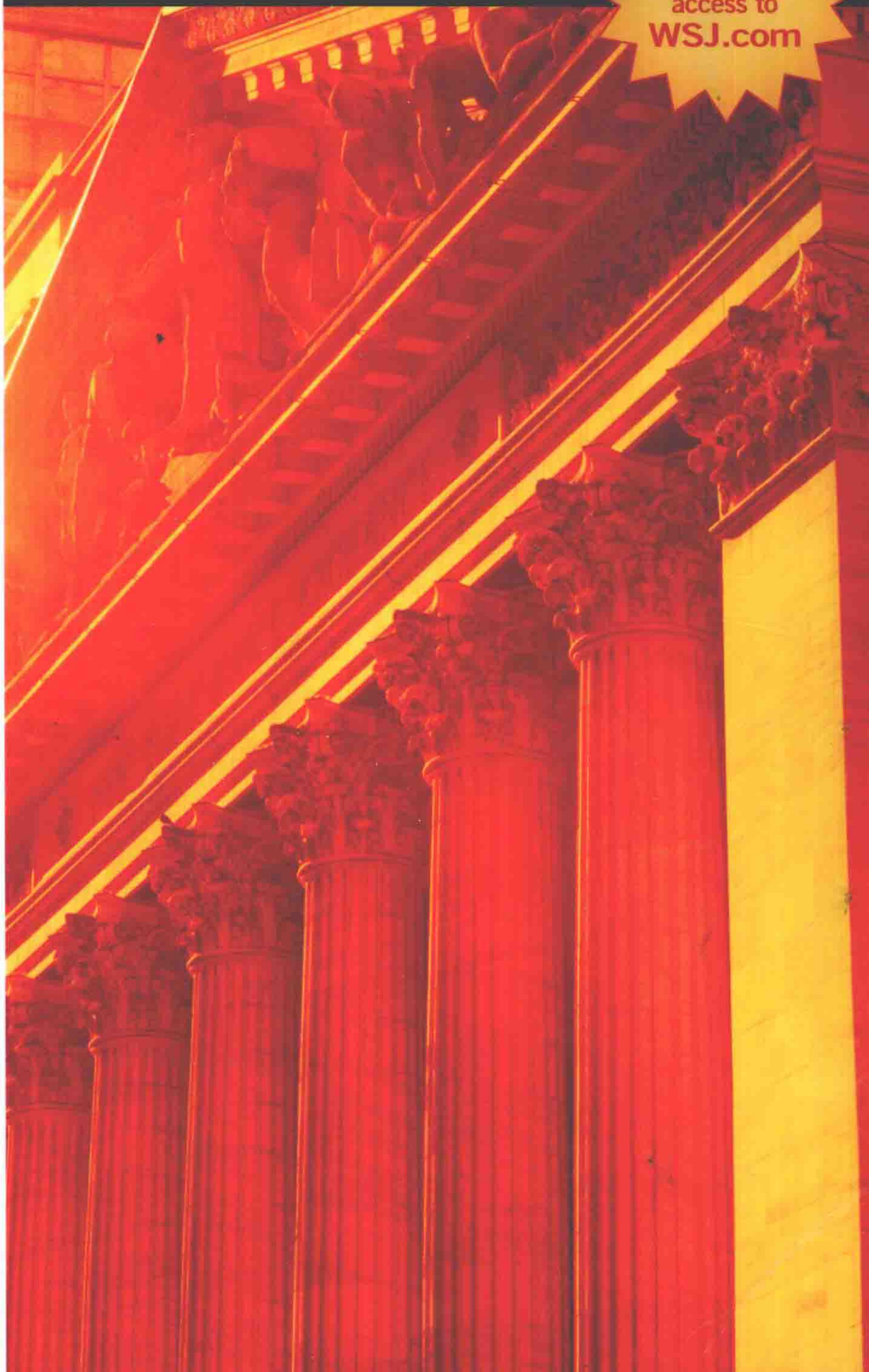

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Cover image "©Harald Sund/The Image Bank"

This book was set in Garamond Light by Binghamton Valley Composition
and printed and bound by Hamilton Printing. The cover was printed by Lehigh Press.

This book is printed on acid-free paper.

ISBN 0-471-39389-4

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

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His current research interests are in the areas of cellular manufacturing operations strategy, business process design, organization learning, and technology. A study investigating the productivity of 738 researchers in the field of operations management ranked Dr. Shafer in the top 20 in terms of both publication quality and research productivity. His publications have appeared in journals such as *Management Science,* the *Journal of Operations Management, Decision Sciences, International Journal of Production Research, OMEGA, IEEE Transactions on Engineering Management, International Journal of Operations and Production Management, International Journal of Purchasing and Materials Management, Production and Inventory Management Journal, Journal of Corporate Accounting and Finance,* and *Project Management Journal.* Dr. Shafer is active in several professional societies including the Decision Sciences Institute, the Institute for Operations Research and the Management Sciences, and the Production Operations Management Society, and has made over a dozen presentations at the national meetings of these organizations. Additionally, he is a former member of the Board of Advisors of SOLE—The International Society of Logistics, is the current Membership Services Coordinator of the Decision Sciences Institute, and is certified in Production and Inventory Management (CPIM) by the American Production and Inventory Control Society. Dr. Shafer is a native of Cincinnati, Ohio. For fun he enjoys working out, tennis, golf, snow skiing, concerts, and playing guitar. Scott and his wife Nikki have three children, Brianna, Sym, and Kacy.

Jack R. Meredith is Professor of Management and Broyhill Distinguished Scholar and Chair in Operations at the Babcock Graduate School of Management at Wake Forest University. He received his undergraduate degrees in engineering and mathematics from Oregon State University and his PhD and MBA from the University of California, Berkeley. During his undergraduate studies he worked for Ampex Corporation and Hewlett-Packard Company as a mechanical engineer. Following the award of his undergraduate degrees he worked as an astrodynamicist for Douglas Aircraft Company, and then TRW Systems Group on the Apollo Space Program.

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Preface

Our goal for this textbook was to provide a short, inexpensive book that covered the introductory, basic material for the operations management course. This would allow the instructor to custom tailor the course through current online content, supplementary cases, and other materials for each unique class. Although we wanted a brief, supplementary-type book so that we could add other material, we have colleagues who need a short book because they only have a half-semester module for the topic. Others may need to include another course's material (e.g., management science, statistics, information systems) in the rest of the quarter or semester.

We also wanted a contemporary book that included topics that operations managers are currently facing such as demand management, rapid prototyping, online B2B marketplaces, contract manufacturing, critical chain, channel assembly, and the experience economy, even if these topics didn't fit very well with the standard presentation of topics in operations textbooks. Moreover, we wanted a book that was written with the marketing or finance major in mind—what do these students need to know about operations to help them in their careers? Certainly not shop floor control and many of the other details we traditionally teach in our operations management classes! Finally, we wanted a text that used primarily service examples for illustration, even if some of the topics such as inventory management were product-based, since the great majority of our students will be employed in service organizations.

Quantitative aspects were especially challenging. Initially we wanted only realistic problems that real managers would encounter. Upon further reflection, we realized that in several instances the inclusion of quantitative material is an effective way to illustrate key concepts such as the trade-off between holding and ordering costs. Hence, we tossed much of the heavier quantitative material, keeping only discussions and examples that would help illustrate a particular concept to a nonoperations manager.

Our approach here is to supplement our treatment of traditional operations management topics with links to appropriate and timely content available on the *Wall Street Journal's* online website. To accomplish this, each chapter contains an end of chapter exercise that directs student to an area of the *Wall Street Journal's* Web site relevant to the material in that particular chapter. Additional supplementary material is referenced and annotated in the Instructor's Manual including cases, books, video clips, and readings for each of the 14 textbook chapters. The annotation is intended to help instructors select the most appropriate materials for their unique course. There are also brief caselettes at the end of each chapter in the text that we have personally class-tested and found can form the basis of an interesting class discussion.

The result of our thinking just described is 14 chapters organized in what we believe to be the most common order of teaching the topics. Yet, the chapters are deliberately constructed and written as stand-alone entities so they can be selected independently from the others, used in a different order if desired, or even selectively used or not used as needed in a course.

We start with the normal overview of operations in Chapter 1, "The Nature of Operations," where we talk about the systems view, the transformation process, typical operations activities, the process versus functional approach to management, and the new concept of the "experience economy." Chapter 2, "Business Strategy and Global Competitiveness," starts our discussion of the role of operations in the organization from a strategic point of view. Here we talk about various strategic operations frameworks such as the sand cone model and performance frontiers, as well as the strategic concepts of core competencies, the balanced scorecard, supply chain management, and mass customization. Following this, we move into another strategic aspect of operations with Chapter 3, "Quality Management," where we discuss quality management, process capability, and quality control. Chapter 4, "Business Process Design" builds on the foundation established in the Quality Managment chapter and addresses the radical redesign of business processes. Chapter 5, "Products/Service Design," Chapter 6, "Transformation System Design,"

Chapter 7, "Forecasting," and Chapter 8, "Capacity and Location Planning," cover the up-front planning aspects of operations such as process-flow analysis, theory of constraints, the psychology of waiting, and the threat of disruptive technologies. Following these, Chapter 9, "Schedule Management;" Chapter 10, "Supply Chain Management;" Chapter 11, "Inventory Management;" Chapter 12, "Material Requirements Planning;" and Chapter 13, "Just-in-Time Systems," cover the ongoing operational aspects such as channel assembly, revenue management, online B2B marketplaces, synchronous manufacturing, e-operations, JIT in services, the bullwhip effect, the demand chain, contract manufacturing, and enterprise resource planning. Chapter 10 includes a supplement on *The Beer Game* since so many MBA classes now include this in their in-class exercises. Chapter 14, "Project Management," completes the text with coverage of a topic that continues to explode in popularity and need. The chapter includes a section covering Goldratt's concept of the critical chain.

We intentionally changed the textual flow of material in the chapters away from the current trend. Instead of fracturing the material flow by adding sidebars, examples, applications, solved problems, and so forth, in a frantic attempt to keep the students' interest and attention, we instead worked these directly into the discussions to attain a smoother, clearer flow. We also altered the end-of-chapter materials by cutting down the questions to just a few that would intrigue and engage students. We similarly limited the bibliography to what would be of interest to current or soon-to-be entry to midlevel managers. We also considered the caselettes to be of interest for this level of student. For those chapters in which exercises are included, they are intended only to help illustrate the concept we are trying to convey rather than make experts out of the students. As noted earlier, the Instructor's Manual includes suggestions for readings, cases, videos, and other course supplements that we have found to be particularly helpful for introductory operations management classes.

We encourage users of this book to send us their comments about how they like this concept of a text. Tell us if there is something we missed that you would like to see in the next edition (or the Instructor's Manual or web site) or if there is perhaps material that is unneeded for this audience. Also, please tell us about any errors you uncover, or if there are other elements of the book you like or don't like. We hope to continue keeping this a living, dynamic project that evolves to meet the needs of the business school audience, an audience whose needs are also evolving as our economy and society twist and change.

We wish to thank the many reviewers of our proposal and manuscript: William C. Giaque, Brigham Young University; James Hill, Vanderbilt University; James K. Ho, University of Illinois at Chicago; Christos Koulamas, Florida International University; Dennis Krumwiede, Idaho State University; Sara Ann McComb, University of Massachusetts-Amherst; Daniel G. Shimshak, University of Massachusetts-Boston; and Nancy C. Weida, Bucknell University.

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CHAPTER 1

The Nature of Operations

CHAPTER IN PERSPECTIVE

This first chapter serves as an introduction to the field of operations management. At the beginning of the chapter, *operations* is defined as the activities associated with transforming inputs into useful outputs in order to create a result of value. It is also shown that the actual production system is defined in terms of environment, inputs, transformation system, outputs, and the mechanism used for monitoring and control. The four primary ways that value can be added to an entity and the major subject areas within operations are also discussed.

The chapter overviews two alternative ways for organizing work activities. In the traditional functional approach, companies organize activities on the basis of the type of work performed. With this approach, operations, marketing, and finance are defined as the three core functions. Recently, however, many companies have found that they can significantly improve organizational efficiency and effectiveness by organizing activities on the basis of specific value-creating processes.

INTRODUCTION

- Facing increased competition and customers who are smarter, more demanding, and less brand-loyal, McDonald's is reevaluating the way it makes some of the items on its menu. For example, it is considering a switch to a hamburger bun that does not require toasting. In trial tests, customers seemed to prefer the new bun's taste and texture. Furthermore, not toasting buns should translate into substantial cost savings due to reduced preparation time and the elimination of commercial toasting equipment. At first, such savings may seem trivial; however, consider that McDonald's processes several billion buns for its hamburgers, chicken, and fish sandwiches (Gibson 1995).

- Getting the Olympic flame to Atlanta for the summer Olympics of 1996 was a major undertaking. Ten thousand runners carried the flame 15,000 miles, passing through 42 states in 84 days. More than two years of planning went into this operation. For example, plans had to be coordinated with 2970 local police jurisdictions. Additionally, plans had to be made to deal with rush-hour traffic, no-show runners, or runners who were not able to complete their leg of the relay. In all, it was estimated that the Olympic flame relay cost in the neighborhood of $20 million, not including transportation, computers, and communication equipment used to support the project (Ruffenach 1996).

- It is not well known that the Kmart and Wal-Mart chains both date back to 1962. By 1987 Kmart was clearly dominating the discount chain race, with almost twice as many stores and sales of $25.63 billion to Wal-Mart's $15.96 billion. However, for the retail year that ended in January 1991, Wal-Mart had overtaken Kmart, with sales of $32.6 billion to Kmart's sales of $29.7 billion. Interestingly, although Wal-Mart had taken the lead in sales in 1991, it still had fewer stores—1721 to Kmart's 2330. By the 2000 retail year, Wal-Mart had clearly established itself as the dominant discount chain, with sales of $188.1 billion to Kmart's $36.4 billion. Perhaps equally telling is the shift in market share experienced by these two companies. For the period from 1987 to 1995 Kmart's market share declined from 34.5 percent to 22.7 percent, while Wal-Mart's increased from 20.1 percent to 41.6 percent.

  What accounts for this reversal in fortunes? Kmart's response to the competition from Wal-Mart was to build on its marketing and merchandising strengths and invest heavily in national television campaigns using high-profile spokespeople such as Jaclyn Smith (a former Charlie's Angel). Wal-Mart took an entirely different approach and invested millions of dollars in operations in an effort to lower costs. For example, Wal-Mart developed a company-wide computer system to link cash registers to headquarters, thereby greatly facilitating inventory control at the stores. Also, Wal-Mart developed a sophisticated distribution system. The integration of the computer system and the distribution system meant that customers would rarely encounter out-of-stock items. Further, the use of scanners at the checkout stations eliminated the need for price checks. By Kmart's own admission, its employees were seriously lacking the skills needed to plan and control inventory effectively (Duff and Ortega 1995).

These brief examples highlight the diversity and importance of operations. Take the description of McDonald's. This example provides a glimpse of two themes that are central to operations: *customer satisfaction* and *competitiveness*. This example also illustrates a more subtle point—that improvements made in operations can simultaneously increase customer satisfaction and lower costs. The Wal-Mart example demonstrates how a company obtained a substantial competitive advantage by improving basic operational activities such as controlling its inventory. Finally, all three examples illustrate that the field of operations is as applicable to service organizations as it is to manufacturing.

In an international marketplace consumers purchase their products from the provider that offers them the most value for their money. To illustrate, you may be doing your course assignments on a Japanese notebook computer, driving in a German automobile, and watching a sitcom on a television made in Taiwan while cooking your food in a Korean microwave. However, most of your services—banking, insurance, personal care—are probably domestic, although some of these may also be owned by foreign corporations. There is a reason why most services are produced by domestic firms while products may be produced in part, or wholly, by foreign firms, and it concerns an area of business known as operations.

A great many societal changes that are occurring today intimately involve activities associated with operations. For example, there is great pressure among competing nations to increase national productivity, and many politicians and national leaders decry America's poor progress in improving productivity growth in comparison with that of other nations. Similarly, businesses are conducting a national crusade to improve the quality of their offerings in both products and services (though sometimes we consumers wonder if this isn't just another marketing gimmick). As we will see, increasing productivity and improving quality are primary objectives of operations management.

Another characteristic of our modern society is the explosion of new technology. Technologies such as fax machines, e-mail, notebook computers, personal digital assistants, and the Web, to name a few, are profoundly affecting business and are fundamentally changing the nature of work. For example, many banks are shifting their focus from building new branch locations to using the Web as a way to establish and develop new customer relationships. Banks rely on technology to carry out more routine activities as well, such as transferring funds instantly across cities, states, and oceans. Our industries also rely increasingly on technology: robots carry and weld parts and workerless, dark "factories of the future" turn out a continuing stream of products.

This exciting, competitive world of operations is at the heart of every organization and, more than anything else, determines whether the organization survives in the international marketplace or disappears into bankruptcy or a takeover. It is this world that we will be covering in the following chapters.

OPERATIONS

Why do we argue that operations should be considered the heart of every organization? Fundamentally, organizations exist to create value, and operations involves tasks that create value. Regardless of whether the organization is for-profit or not-for-profit, primarily service or manufacturer, public or private, it exists to create value. Thus, even nonprofit organizations like the Red Cross strive to create value for the recipients of their services in excess of their costs. Moreover, this has always been true, from the earliest days of bartering to the modern-day corporations.

Consider McDonald's again. This firm uses a number of inputs, including ingredients, labor, equipment, and facilities; transforms them in a way that adds value to them (e.g., by frying); and obtains an output, such as a chicken sandwich, that can be sold at a profit. This conversion process, termed a *production system*, is illustrated

in Figure 1.1. The elements of the figure represent what is known as a **system**[1]**: a purposeful collection of people, objects, and procedures for operating within an environment**. Note the word *purposeful*; systems are not merely arbitrary groupings but goal-directed or purposeful collections. Managing and running a production system efficiently and effectively is at the heart of the operations activities that will be discussed in this text. Since we will be using this term throughout the text, let us formally define it. ***Operations*** is concerned with transforming inputs into useful outputs and thereby adding value to some entity; this constitutes the primary activity of virtually every organization.

Not only is operations central to organizations; it is also central to people's personal and professional activities, regardless of their position. People too must operate productively, adding value to inputs and producing quality outputs, whether those outputs are information, reports, services, products, or even personal accomplishments. Thus, operations should be of major interest to every reader, not just professionally but also personally.

Systems Perspective

As Figure 1.1 illustrates, a production system is defined in terms of environment, inputs, transformation system, outputs, and the mechanism used for monitoring and control. The environment includes those things that are outside the actual production system but that influence it in some way. Because of its influence, we need to consider the environment, even though it is beyond the control of decision makers within the system.

For example, a large portion of the inputs to a production system are acquired from the environment. Also, government regulations related to pollution control and workplace safety affect the transformation system. Think about how changes in customers' needs, a competitor's new product, or a new advance in technology can influence the level of satisfaction with a production system's current outputs. As these examples show, the environment exerts a great deal of influence on the production system.

Because the world around us is constantly changing, it is necessary to monitor the production system and take action when the system is not meeting its goals. Of course, it may be that the current goals are no longer appropriate, indicating a need to revise the goals. On the other hand, it may be determined that the goals are fine but that the inputs or transformation system or both should be acted upon in some way. In either case, it is important to continuously collect data from the environment, the transformation system, and the outputs. Then, on the basis of an analysis of these data, appropriate actions can be devised to enhance the system's overall performance.

Thinking in terms of systems provides decision makers with numerous advantages. To begin, the systems perspective focuses on how the individual components that make up a system interact. Thus, the systems perspective provides decision makers with a broad and complete picture of an entire situation. Furthermore, the systems perspective emphasizes the relationships between the various system components.

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[1]Note the word *system* is being used here in a broad sense and should not be confused with more narrow usages such as information systems, planning and control systems, or performance evaluation systems.

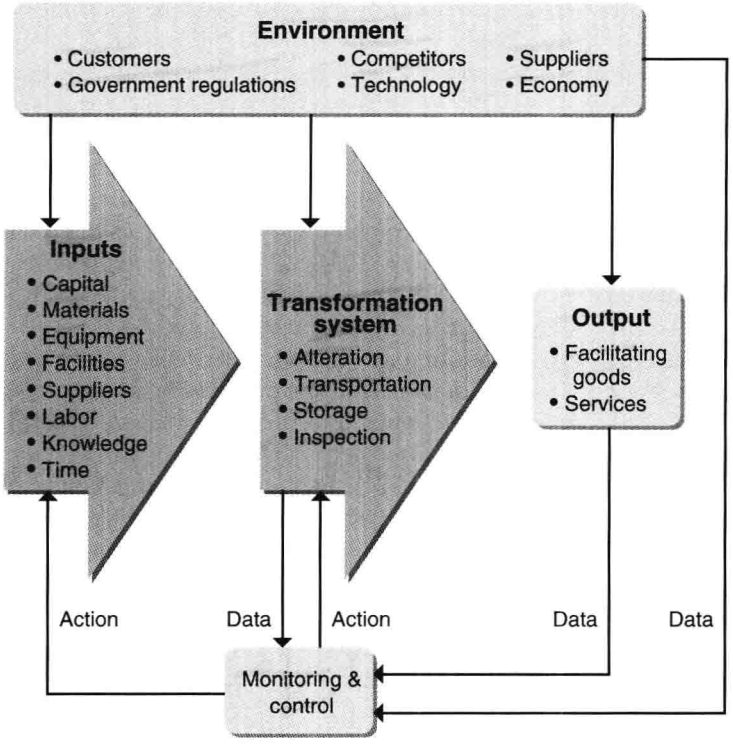

Figure 1.1 The production system.

Without considering these relationships, decision makers are prone to a problem called *suboptimization*. Suboptimization occurs when one part of the system is improved to the detriment of other parts of the system, and perhaps the organization as a whole. An example of suboptimization from the medical field is "the operation was a success but the patient died!" As another example of suboptimization, suppose that a retailer decides to broaden its product line in an effort to increase sales. Such a decision could actually end up hurting the retailer as a whole if it does not have sufficient shelf space available to accommodate the broader product line, sales and service personnel that are knowledgeable about the new products, or if the broader product line increases inventory-related costs more than profits from the increased sales. The point of this example is that decisions need to be evaluated in terms of their effect on the entire system, not simply in terms of how they will affect one component of the system.

It is interesting to note that the components of systems are often themselves systems, called *subsystems*. For example, a factory that assembles personal computers is a system. Within this system there are many subsystems, such as the system that reports financial information, the system for assembling the computers, the system for ordering the raw materials, the system for designing new products, and the system for recruiting and hiring workers. And many of these subsystems could be further divided into sub-subsystems. To illustrate, the system that reports financial information may be composed of a system that reports information to sources outside the

organization and another system that provides financial information to employees within the organization.

It also stands to reason that since systems can be divided into component subsystems, it should also be possible to combine them into larger systems. This is indeed the case. Consider the example of the personal computer assembly plant. This plant may be just one of a number of plants making up a particular division of the company. Thus, combining these plants would form a system corresponding to the division of this company. Furthermore, combining the divisions of the company would create a system for the whole company. This logic could be extended to creating systems for the entire industry, and all the way up to creating a system for the entire economy.

This discussion highlights the importance of defining a system's boundary appropriately. Specifically, defining a boundary determines what a decision maker will and will not consider, since things outside the system boundary are considered to be part of the environment and beyond the decision maker's control. Defining a system boundary is important, because if it is defined too narrowly, important relationships among system components may be omitted. On the other hand, extending the boundary increases the complexity and costs associated with developing and using the model. Unfortunately, determining the system boundary is more of an art than a science and is based on the experience, skill, and judgment of the analyst.

Regardless of where the system boundary is defined, all production systems receive inputs from their environments, transform these inputs, and create value in the form of outputs. In the remainder of this section, we elaborate on inputs, the transformation system, and outputs.

Inputs

The set of inputs used in a production system is more complex than might be supposed and typically involves many other areas such as marketing, finance, engineering, and human resource management. Obvious inputs include facilities, labor, capital, equipment, raw materials, and supplies. Supplies are distinguished from raw materials by the fact that they are not usually a part of the final output. Oil, paper clips, pens, tape, and other such items are commonly classified as supplies because they only aid in producing the output.

Another very important but perhaps less obvious input is knowledge of how to transform the inputs into outputs. The employees of the organization hold this knowledge. Finally, having sufficient time to accomplish the operations is always critical. Indeed, the operations function quite frequently fails in its task because it cannot complete the ***transformation activities*** within the required time limit.

Transformation System

The transformation system is the part of the system that adds value to the inputs. Value can be added to an entity in a number of ways. Four major ways are described here.

1. *Alter.* Something can be changed structurally. That would be a *physical* change, and this approach is basic to our manufacturing industries where goods are cut, stamped, formed, assembled, and so on. We then go out and

buy the shirt, or computer, or whatever the good is. But it need not be a separate object or entity; for example, what is altered may be *us*. We might get our hair cut, or we might have our appendix removed.

Other, more subtle, alterations may also have value. *Sensual* alterations, such as heat when we are cold, or music, or beauty may be highly valued on certain occasions. Beyond this, even *psychological* alterations can have value, such as the feeling of worth from obtaining a college degree or the feeling of friendship from a long-distance phone call.

2. *Transport.* An entity, again including ourselves, may have more value if it is located somewhere other than where it currently is. We may appreciate having things brought to us, such as flowers, or removed from us, such as garbage.
3. *Store.* The value of an entity may be enhanced for us if it is kept in a protected environment for some period of time. Some examples are stock certificates kept in a safe-deposit box, our pet boarded at a kennel while we go on vacation, or ourselves staying in a motel.
4. *Inspect.* Last, an entity may be more valued because we better understand its properties. This may apply to something we own, plan to use, or are considering purchasing, or, again, even to ourselves. Medical exams, elevator certifications, and jewelry appraisals fall into this category.

Thus, we see that value may be added to an entity in a number of different ways. The entity may be changed directly, in space, in time, or even just in our mind. Additionally, value may be added using a combination of these methods. To illustrate, an appliance store may create value by both storing merchandise and transporting (delivering) it. There are other, less frequent, ways of adding value as well, such as by "guaranteeing" something. These many varieties of transformations, and how they are managed, constitute some of the major issues to be discussed in this text.

Outputs

Two types of outputs commonly result from a production system: services and products. Generally, products are physical goods, such as a personal computer, and services are abstract or nonphysical. More specifically, we can consider the characteristics in Table 1.1 to help us distinguish between the two.

However, this classification may be more confusing than helpful. For example, consider a pizza delivery chain. Does this organization produce a product or provide a service? If you answered "a service," suppose that instead of delivering its pizzas to the actual consumer, it made the pizzas in a factory and sold them in the frozen-food section of grocery stores. Clearly the actual process of making pizzas for immediate consumption or to be frozen involves basically the same tasks, although one may be done on a larger scale and use more automated equipment. The point is, however, that both organizations produce a pizza, and defining one organization as a service and the other as a manufacturer seems to be a little arbitrary. In addition, both products and services can be produced as commodities or individually customized.

We avoid this ambiguity by adopting the point of view that *any physical entity*

TABLE 1.1 • Characteristics of Products and Services

Products	Services
Tangible	Intangible
Minimal contact with customer	Extensive contact with customer
Minimal participation by customer in the delivery	Extensive participation by customer in the delivery
Delayed consumption	Immediate consumption
Equipment-intense production	Labor-intense production
Quality easily measured	Quality difficult to measure

accompanying a transformation that adds value is a ***facilitating good*** (e.g., the pizza). In many cases, of course, there may be no facilitating good; we refer to these cases as *pure services.*

The advantage of this interpretation is that every transformation that adds value is simply a service, either with or without facilitating goods! If you buy a piece of lumber, you have not purchased a product. Rather, you have purchased a bundle of services, many of them embodied in a facilitating good: a tree-cutting service, a saw mill service, a transportation service, a storage service, and perhaps even an advertising service that told you where lumber was on sale. We refer to these services as a bundle of "benefits," of which some are tangible (the sawed length of lumber, the type of tree) and others are intangible (courteous sales clerks, a convenient location, payment by charge card). Some services may, of course, even be negative, such as an audit of your tax return. In summary, ***services*** are bundles of benefits, some of which may be tangible and others intangible, and they may be accompanied by a facilitating good or goods.

Firms often run into major difficulties when they ignore this aspect of their operations. They may think of and even market themselves as a "lumberyard" and not as providing a bundle of services. They may recognize that they have to include certain tangible services (such as cutting lumber to the length desired by the customer) but ignore the intangible services (charge sales, having a sufficient number of clerks).

While the broader perspective of the facilitating good concept helps clarify the ambiguity associated with whether an organization produces a product or service, it also blurs the distinction between operations and marketing. To illustrate, earlier we defined operations as including the tasks that add value. However, when outputs are viewed broadly as a bundle of benefits, it becomes clear that marketing, as well as other areas of an organization, contribute to the value outputs provide.

Another reason for not making a distinction between manufacturing and services is that making such a distinction can be harmful. Specifically, when a company thinks of itself as a manufacturer it tends to focus on measures of internal performance such as efficiency and utilization; and when companies classify themselves as services they tend to focus externally and ask questions such as, "How can we serve our customers better?" This is not to imply that improving internal performance measures is not desirable. Rather, it suggests that improved customer service should be the primary impetus for all improvement efforts. It is generally not advisable to seek internal