Introduction to MATERIALS MANAGEMENT

NINTH EDITION

Stephen N. Chapman | Ann K. Gatewood | J. R. Tony Arnold | Lloyd M. Clive

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PREFACE

Introduction to Materials Management is an introductory text written for students in community colleges and universities as well as professionals involved in supply chain and other materials management positions. It is used in technical programs, such as industrial engineering and manufacturing engineering; in business, operations and supply chain management programs; and by those already in industry, whether or not they are working in materials management.

This text has been widely adopted by colleges and universities not only in North America but also in many other parts of the world. The Association for Supply Chain Management (ASCM) (formerly APICS) organization recommends this text as the reference for certification preparation for CPIM examinations. In addition, the text is used by production and inventory control societies around the world, including South Africa, Australia, New Zealand, Germany, France, and Brazil, and by consultants who present in-house courses to their customers.

Introduction to Materials Management covers all the basics of supply chain management, manufacturing planning and control systems, purchasing, physical distribution, lean and quality management. The material, examples, questions, and problems lead the student logically through the text. The writing style is simple and user-friendly—both instructors and students who have used the book attest to this.

NEW TO THIS EDITION

- All chapters have been updated to reflect new techniques and technology.
- Several additional case studies have been added.
- Additional special topic boxes have been added relating chapter topics to discussions of interest, including nonmanufacturing settings such as service industries, and recent responses of supply chains to risk events.
- Several end-of-chapter problems have been altered.
- A completely new chapter discussing the fundamentals of supply chain management has been added which gives an overall coverage of supply chain concepts as well as tying together several supply chain related issues that previously appeared in the chapters as individual topics.
- Additional information has been included on warehousing, including some impacts of technology and lean principles applied to warehouse management.
- Additional information has been added on the impact technology has on physical distribution.
- Management of special demand situations has been included as it applies to lean production.

In addition, we have retained several features from previous editions:

- Key terms listed at the end of each chapter
- Example problems within the chapters
- Chapter summaries
- Questions and problems at the end of each chapter

APPROACH AND ORGANIZATION

Materials management means different things to different people. In this textbook, materials management includes all activities in the flow of materials from the supplier to the consumer. Such activities include physical supply, operations planning and control, and physical distribution. Other terms sometimes used in this area are *business logistics* and *supply chain management*. Often, the emphasis in business logistics is on transportation and distribution systems with little concern for what occurs in the factory. Whereas some chapters in this text are devoted to transportation and distribution, emphasis is placed on operations planning and control.

Distribution and operations are managed by planning and controlling the flow of materials through them and by using the system's resources to achieve a desired customer service level. These activities are the responsibility of materials management and affect every department in a manufacturing business. If the materials management system is not well designed and managed, the distribution and manufacturing system will be less effective and more costly. Anyone working in manufacturing or distribution should have a good basic understanding of the factors influencing materials flow. This text aims to provide that understanding and also includes chapters on quality management and lean production.

ASCM (formerly APICS) defines the body of knowledge, concepts, and vocabulary used in production and inventory control. Establishing standard knowledge, concepts, and vocabulary is essential both for developing an understanding of production and inventory control and for making clear communication possible. Where applicable, the definitions and concepts in this text subscribe to ASCM vocabulary and concepts.

The first six chapters of *Introduction to Materials Management* cover the basics of production planning and control. Chapter 7 discusses important factors in the management of the supply chain. Chapter 8 examines specific topics in purchasing, and Chapter 9 discusses forecasting. Chapters 10, 11, and 12 look at the fundamentals of inventory management. Chapter 13 discusses physical inventory and warehouse management, and Chapter 14 examines the elements of distribution systems, including transportation, packaging, and material handling. Chapter 15 covers factors influencing product and process design. Chapter 16 looks at the philosophy and environment of just-in-time and lean production and explains how operations planning and control systems relate to just-in-time and lean production. Chapter 17 examines the elements of total quality management and six sigma quality approaches.

Alternate Versions

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ACKNOWLEDGMENTS

Although it has been several years since the passing of Tony Arnold, the original author, he developed and refined a clear vision for the concepts and goals that this book was intended to achieve. He also clearly expressed those points to the present authors, knowing that keeping those concepts and goals constantly in mind while new editions and new material was added would continue to let new editions be relevant. This ninth edition continues to reflect the original vision of providing a clear and understandable introductory look at the field of Materials Management.

Help and encouragement have come from a number of valued sources, among them friends, colleagues, and students. We thank the many users of the book who have provided comments and suggestions. We especially wish to thank members of the ASCM CPIM Committees who have provided specific guidance for the revision. Additionally, we would like to thank our reviewers, past and present, for their help in suggesting new content: Andrea Prud'homme (The Ohio State University), Steven Rudnicki (Westinghouse Electric Company), Jim Caruso (Covidien), Frank Montabon (Iowa State University), Mark Hardison (SIGA Technologies), and John Kanet (The University of Dayton).

Overall, this book is dedicated to those who have taught us the most—our students.

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CHAPTER ONE

INTRODUCTION TO MATERIALS MANAGEMENT

INTRODUCTION

What is the source of wealth? Wealth is measured by the amount of goods and services produced. For example, the wealth of a country is measured by its gross national product—the output of goods and services produced by the nation in a given time. Goods are physical objects, something one can touch, feel, or see. Services are the performance of some useful function such as banking, medical care, restaurants, clothing stores, or social services.

Although rich natural resources may exist in an economy, such as mineral deposits, farmland, and forests, these are only potential sources of wealth. A production function is needed to transform these resources into useful goods. The transformation process begins with extracting minerals from the earth, farming, lumbering, or fishing, and then using these resources to manufacture useful products.

There are many stages between the extraction of resource material and the final consumer product. At each stage in the development of the final product, value is added, thus creating more wealth. If ore is extracted from the earth and sold, wealth is gained from the efforts, but those who continue to transform the raw material will gain more and usually far greater wealth. Japan is a prime example of this. It has very few natural resources and imports most of the raw materials it needs. However, the Japanese have developed one of the wealthiest economies in the world by transforming the raw materials they purchase and adding value to them through manufacturing.

Manufacturing companies are in the business of converting raw materials to a form that is of far more value and use to the consumer than the original raw materials. Logs are converted into tables and chairs, iron ore into steel, and steel into cars and refrigerators. This conversion process, called *manufacturing* or *production*, makes a society wealthier and creates a better standard of living.

To get the most value out of resources, production processes must be designed so that they make products most efficiently. Once the processes exist, operations are managed so that goods are produced most economically. Managing the operation means planning for and controlling the resources used in the process: labor, capital, and material. All are important, but the foremost method in which management plans and controls operations is through the flow of materials. The flow of materials in turn controls the performance of the process. If the right materials in the right quantities are not available at the right time, the process cannot produce what it should. Labor and machinery will be poorly utilized. The profitability, and even the existence, of the company will be threatened.

OPERATING ENVIRONMENT

Operations management works in a complex environment affected by many factors. Among the most important are government regulation, the economy, competition, customer expectations, and quality.

Government. Regulation of business by the various levels of government is extensive. Regulation applies to such areas as the environment, safety, product liability, and taxation. Government, or the lack of it, affects the way business is conducted.

Economy. General economic conditions influence the demand for a company's products or services and the availability of inputs. During economic recession, the demand for some products may decrease while demand for others may increase. Materials and labor shortages or surpluses influence the decisions management makes. Shifts in the age of the population, needs of ethnic groups, low population growth, increased free trade between countries, and increased global competition all contribute to changes in the marketplace.

Competition. Competition is more significant today than ever before.

- Manufacturing companies face competition from foreign competitors throughout the world due to the global economy.
- Transportation and the movement of materials are more efficient and less costly than they used to be.
- Worldwide communications are fast, effective, and cheap. Information and data can be moved instantly around the globe. The internet allows buyers to search out new sources of supply from anywhere in the world as easily as they can from local sources.

Customers. Both consumers and industrial customers have become much more demanding, and suppliers have responded by improving the range of characteristics they offer. Some of the characteristics and selection customers expect in the products and services they buy are:

- A fair price.
- Higher (perfect) quality products and services.
- Fast and accurate delivery lead time.
- Better presale and after-sale service.
- Product and volume flexibility.

Quality. Since competition is international and aggressive, successful companies provide quality that not only meets customers' high expectations but also exceeds them.

Order Qualifiers and Order Winners

Generally, a supplier must meet set minimum requirements to be considered a viable competitor in the marketplace. Customer requirements may be based on price, quality, delivery, and so forth and are called **order qualifiers**. For example, the price for a certain type of product must fall within a certain range for the supplier to be considered by potential customers. But being considered does not mean winning the order. To win orders, a supplier must have characteristics that encourage customers to choose its products and services over competitors'. Those competitive characteristics, or combination of characteristics, that persuade a company's customers to choose its products or services are called **order winners**. They provide a competitive advantage for the firm. Order winners change over time and may well be different for different markets. For example, fast delivery may be vital in one market but not in another. Characteristics that are order winners today probably will not remain so, because competition will try to copy winning characteristics, and the needs of customers will change.

It is very important that a firm understands the order winners and order qualifiers for each of its products or services and in each of its markets in order to drive the manufacturing and corporate strategy. Since it is virtually impossible to be the best in every dimension of competition, firms should in general strive to provide at least a minimal level of acceptance for each of the order qualifiers but should try to be the *best* in the market for the order winner(s).

One also should recognize that the order winners and qualifiers for any product/market combination are not static. Not only will customers change perspectives as competitors jockey for position, but the order winners and qualifiers will also often change based on the concepts of the product life cycle. Most products go through a life cycle, including introduction, growth, maturity, and decline. For example, in the introduction phase, design

and availability are often much more important than price. Quality and delivery tend to have increased importance during growth, while price and delivery are often the order winners for mature products. This life cycle approach is complicated in that the duration of the life cycle will be very different for different products. Although some products have life cycles of many years, the life cycle of other products (certain toys or electronics, for example) can be measured in months or even weeks.

Manufacturing Strategy

A highly market-oriented company will focus on meeting or exceeding customer expectations and on order winners. In such a company, all functions must contribute toward a winning strategy. Thus, operations must have a strategy that allows it to supply the needs of the marketplace and provide fast on-time delivery.

Delivery lead time From the supplier's perspective, delivery lead time is the time from receipt of an order to the delivery of the product. From the customer's perspective, it may also include time for order preparation and transmittal. Most customers want delivery lead time to be as short as possible, and manufacturing must determine a process strategy to achieve this. There are five basic process strategy choices: engineer-to-order, make-to-order, configure-to-order, assemble-to-order, and make-to-stock. Customer involvement in the product design, delivery lead time, and inventory state are influenced by each strategy. Based on the type of products a company makes, and their customer base, a company may determine that more than one process strategy is required. Figure 1.1 shows the effect of each process strategy on lead time.

Engineer-to-order means that the customer's specifications require unique engineering design or significant customization. Usually the customer is highly involved in the product design. Inventory will not normally be purchased until needed by manufacturing. Delivery lead time is long because it includes not only purchase lead time but also design lead time.

Make-to-order means that the manufacturer does not start to make the product until a customer's order is received. The final product is usually made from standard items but may include custom-designed components as well. Delivery lead time is reduced because there is little design time required and inventory is held as raw material.

Configure-to-order means that the customer is allowed to configure a product based on various features and options. Each customer, and order, may be an entirely unique configuration that has never been done before, and the configuration often occurs at

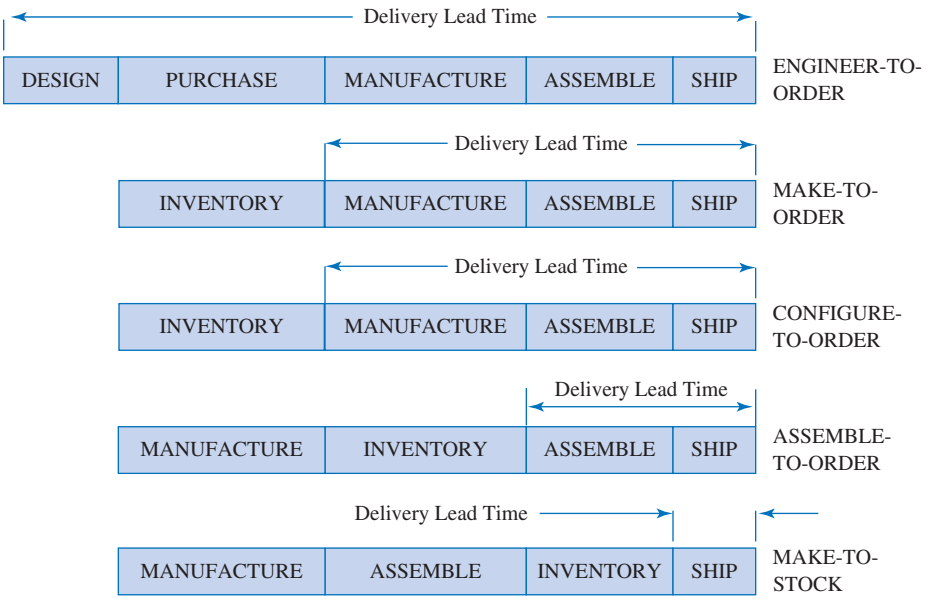

FIGURE 1.1 Manufacturing strategy and lead time.

the beginning of the process. Delivery lead time is reduced because there is no design time required and the different features and options may already be available. Customer involvement includes selecting the features and options desired.

Assemble-to-order means that the product is made from standard components or options that the manufacturer can inventory and assemble according to a customer order. This is usually done at a later stage in the process than configure-to-order. Delivery lead time is reduced further because there is no design time needed and inventory is held ready for assembly. Customer involvement in the design of the product is limited to selecting the assembly options needed.

Make-to-stock means that the supplier manufactures the goods and sells from a finished goods inventory. Delivery lead time is shortest as manufacturing and assembly have already been completed. The customer has little direct involvement in the product design.

Postponement is another application of assemble-to-order, described in the *APICS Dictionary,* 16th edition, as "a product design or supply chain strategy that deliberately delays final differentiation (assembly, production, packaging, tagging, etc.) until the latest possible time in the process. This shifts product differentiation closer to the consumer to reduce the anticipatory risk of producing the wrong product. The practice eliminates excess finished goods in the supply chain."

An example of postponement would be computer printers for a global market that use universal power supplies that can be switched to different voltages. Upon receipt of a customer's order, they are packaged with the appropriate cords, instructions, and labeling. This avoids filling an entire supply chain with expensive printers destined for many different countries. Some basic postponement can be done in a distribution center and often by third party logistics (3PL) providers. Foreign suppliers of appliances, such as vacuum cleaners destined for multiple customers, postpone the packaging of their products, applying customer-specific labels, bar codes, boxes, instructions, and so forth until after receipt of the customer order.

THE SUPPLY CHAIN CONCEPT

There are three phases in the flow of materials. Raw materials flow into a manufacturing company from a physical supply system, they are processed by manufacturing, and finally, finished goods are distributed to end consumers through a physical distribution system. Figure 1.2 shows this system graphically. Although this figure shows only one supplier and one customer, usually the **supply chain** consists of several companies linked in a supply–demand relationship. For example, the customer of one supplier buys a product, adds value to it, and supplies it to yet another customer. Similarly, one customer may have several suppliers and may in turn supply several customers. As long as there is a chain of supplier–customer relationships, they are all members of the same supply chain.

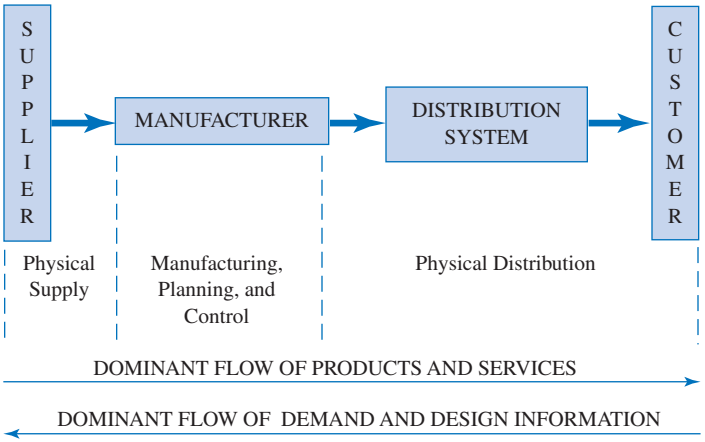

FIGURE 1.2 Supply–production–distribution system.

There are a number of important factors in supply chains:

- The supply chain includes all activities and processes to supply a product or service to a final customer.
- Any number of companies can be linked in the supply chain.
- A customer can be a supplier to another customer, so the total chain can have a number of supplier-customer relationships.
- Although the distribution system can be direct from supplier to customer, depending on the products and markets, it can contain a number of intermediaries (distributors) such as wholesalers, warehouses, and retailers.
- Product or services usually flow from supplier to customer; design, demand information, and cash usually flow from customer to supplier.

Although these systems vary from industry to industry and company to company, the basic elements are the same: supply, production, and distribution. The relative importance of each depends on the costs of the three elements.

Fundamentals of the management of the supply chain will be discussed in Chapter 7.

Performance Metrics

A **metric** is a verifiable measure stated in either quantitative or qualitative terms defined with a reference point. Without metrics, no firm can expect to function effectively or efficiently on a daily basis. Benefits of metrics include:

1. Reporting of data to superiors and external groups for better control.
2. Communicating priorities by the organization.
3. Drawing attention to opportunities for improvement.
4. Keeping processes under control.

Determining the right metrics to use is vital to a company, as metrics communicate expectations, identify problems, direct a course of action, and motivate people. Problems must be anticipated and corrective action taken before they become severe and costly. Companies cannot risk waiting to react until the order cycle is completed and feedback from customers is received.

Today, production control works in a demanding environment shaped by five major challenges:

1. Customers that are increasingly demanding.
2. A supply chain that is large and must be managed.
3. A product life cycle that is getting shorter and shorter.
4. A vast amount of data.
5. An increasing number of alternatives.

A firm typically has a corporate strategy that states how it will treat its customers and what services it will supply. This identifies how a firm will compete in the marketplace. It is the customer who assesses the firm's offering by its decision to buy or not to buy. How metrics link strategy to operations is shown in Figure 1.3. Focus describes the particular activity that is to be measured. Standards are the yardstick that is the basis of comparison on which performance is judged.

There is a difference between performance measurements and performance standards. A **performance measure** must be both quantified and objective and contain at least two

FIGURE 1.3 Metrics context.

parameters. For example, the number of orders per day consists of both a quantity and a time measurement.

Transforming company policies into objectives and specific goals creates **performance standards**. Each goal should have target values. An example of this would be to improve order fill rate to 98% measured by number of lines. Performance standards set the goal, while performance measures reveal how close to the goal the organization reached.

Many companies do not realize the potential benefits of performance measurement, nor do they know how to measure performance, and often try to use them without performance standards. This might occur when the concept of performance measurement and standards is new. Only when standards are put into use can management begin to monitor the company. The old saying "What you do not measure, you cannot control" is as valid today as it was when first stated.

The necessary steps in implementing such a program are as follows:

1. Establish company goals and objectives.
2. Define performance to be measured.
3. State the measurement to be used.
4. Set performance standards.
5. Educate the participants.
6. Make sure the program is consistently applied.
7. Review and adjust as necessary.

Although financial performance has traditionally been the measure of success in most companies, today the focus is on continuous improvement and, with this, an increase in standards. Emphasis should not be placed on a "one-shot" improvement but on such things as the rate of improvement in quality, cost, reliability, innovation, effectiveness, and productivity.

Conflicts in Traditional Systems

In the past, supply, production, and distribution systems were organized into separate functions that reported to different departments of a company. Often, policies and practices of the different departments maximized departmental objectives without considering the effect they would have on other parts of the system. Because the three systems are interrelated, conflicts often occurred. Although each system made decisions that were best for itself, overall company objectives suffered. For example, the transportation department would ship in the largest quantities possible so it could minimize per-unit shipping costs. However, this increased inventory and resulted in higher inventory-carrying costs.

To get the most profit, a company must have at least four main objectives. Examples of these include the following:

1. Provide best customer service.
2. Provide lowest production costs.
3. Provide lowest inventory investment.
4. Provide lowest distribution costs.

These objectives create conflict among the marketing, production, and finance departments because each has different responsibilities in these areas.

Marketing's objective is to maintain and increase revenue; therefore, it must provide the best customer service possible. There are several ways of doing this:

- Maintain high inventories so goods are always available for the customer.
- Interrupt production runs so that a non-inventoried item can be manufactured quickly if required by a customer.
- Create an extensive, and consequently costly, distribution system so goods can be shipped to the customer rapidly.

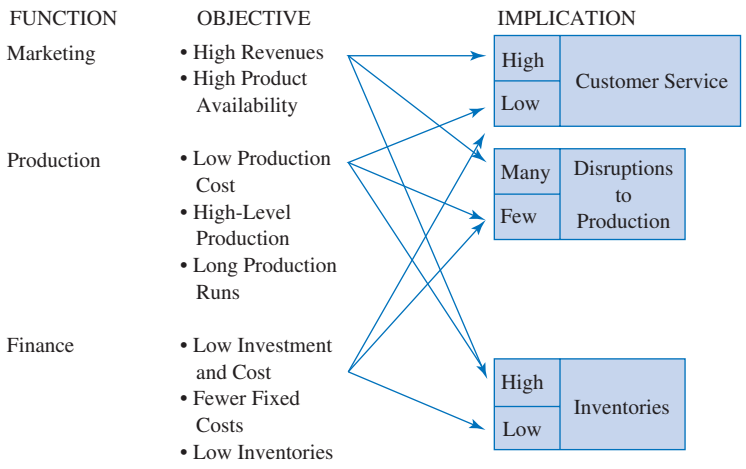

FIGURE 1.4 Conflicting objectives.

Finance must keep investment and costs low. This can be done in the following ways:

- Reduce inventory so inventory investment is at a minimum.
- Decrease the number of plants and warehouses.
- Produce large quantities using long production runs.
- Manufacture only to customer order.

Production must keep its operating costs as low as possible. This can be done in the following ways:

- Make long production runs of relatively few products. Fewer changeovers will be needed and specialized equipment can be used, thus reducing the cost of making the product.
- Maintain high inventories of raw materials and work-in-process so production is not disrupted by shortages.

These conflicts among marketing, finance, and production center on customer service, disruption of production flow, and inventory levels. Figure 1.4 shows this relationship.

Today, the concepts of lean production stress the need to supply customers with what they want, when they want it, and to keep inventories at a minimum. These objectives put further stress on the relationship among production, marketing, and finance. Chapter 16 will discuss the concepts of lean production and how it influences materials management.

One important means of resolving these conflicting objectives is to provide close coordination of the supply, production, and distribution functions. The aim is to balance conflicting objectives to minimize the total of all the costs involved and maximize customer service consistent with the goals of the organization. This requires some type of integrated materials management or logistics organization that is responsible for supply, production, and distribution. The functions of marketing, production, and distribution must coordinate the planning and control of these areas in order to operate under overall company objectives.

WHAT IS MATERIALS MANAGEMENT?

The concept of having one department responsible for the flow of materials, from supplier through production to consumer, thereby minimizing total costs and providing a better level of customer service, is known as **materials management**. Other names include distribution planning and control, supply chain management, and logistics management, but the one used in this text is materials management. As will be discussed in Chapter 16, lean production not only requires efficient individual operations but also requires all operations to work together. A materials management department can improve this coordination by having overall responsibility for material. Its objectives are as follows:

- Maximize the use of the firm's resources.
- Provide the required level of customer service.

Materials management can do much to improve a company's profit. An income (profit and loss) statement for a manufacturing company might look something like the following:

		Dollars	Percent of Sales
Revenue (sales)		$1,000,000	100
Cost of Goods Sold			
Direct Material	$500,000		50
Direct Labor	$200,000		20
Factory Overhead	$200,000		20
Total Cost of Goods Sold		$900,000	90
Gross Profit		$100,000	10

Direct labor and direct material are costs that increase or decrease with the quantity sold. Overhead (all other costs) does not vary directly with sales. For simplicity, overhead is assumed to be constant, even though it is initially expressed as a percentage of sales.

If, through a well-organized materials management department, direct materials can be reduced by 12%, the improvement in profit would be

		Dollars	Percent of Sales
Revenue (sales)		$1,000,000	100
Cost of Goods Sold			
Direct Material	$440,000		44
Direct Labor	$200,000		20
Overhead	$200,000		20
Total Cost of Goods Sold		$840,000	84
Gross Profit		$160,000	16

Profit has been increased by 60%. In other words, managing inventory effectively goes right to the bottom line of a company's profit. To get the same increase in profit ($60,000) by increasing revenue, sales would have to increase to $1.2 million.

		Dollars	Percent of Sales
Revenue (sales)		$1,200,000	100
Cost of Goods Sold			
Direct Material	$600,000		50
Direct Labor	$240,000		20
Overhead	$200,000		17
Total Cost of Goods Sold		$1,040,000	87
Gross Profit		$160,000	13

Example Problem

a. If the cost of direct material is 60%, direct labor is 10%, and overhead is 25% of sales, what will be the improvement in profit if cost of direct material is reduced to 55%?

b. How much will sales have to increase to give the same increase in profit? (Remember, overhead cost is constant.)

ANSWER

a.

	Before Improvement	After Improvement
Revenue (sales)	100%	100%
Cost of Goods Sold		
Direct Material	60%	55%
Direct Labor	10%	10%
Overhead	25%	25%
Total Cost of Goods Sold	95%	90%
Gross Profit	5%	10%

b. $\text{Profit} = \text{sales} - (\text{direct material} + \text{direct labor} + 0.25)$

$= \text{sales} - (0.6 \text{ sales} + 0.1 \text{ sales} + 0.25)$

$= \text{sales} - 0.7 \text{ sales} - 0.25$

$0.1 = 0.3 \text{ sales} - 0.25$

$0.3 \text{ Sales} = 0.35$

$$\text{Sales} = \frac{0.35}{0.3} = 1.17$$

Sales must increase 17% to give the same increase in profit.

Work-in-Process

Inventory not only accounts for the raw materials and purchased components, but is also made up of the product as it is processed into finished goods. This type of inventory is called **work-in-process (WIP)**. WIP is a major investment for many companies, and reducing the amount of time that inventory spends in production is a good way to reduce the costs associated with this investment. Labor, materials, and overhead are applied to goods continuously through-out production, which increases the value of WIP. Further discussion on WIP and reducing it is covered in Chapters 10 and 16.

Example Problem

On average, a company has a 12-week production lead time and an annual cost of goods sold of $36 million. Assuming the company works 50 weeks per year:

a. What is the dollar value of the WIP?

b. If the lead time could be reduced to five weeks, and the annual cost of carrying inventory was 20% of the inventory value, what would be the annual savings?

ANSWER

$$\begin{aligned}
\text{Weekly cost of goods sold} &= \$36{,}000{,}000 \text{ per year}/50 \text{ weeks per year} \\
&= \$720{,}000/\text{week} \\
\text{WIP value at 12 weeks LT} &= 12 \text{ weeks} \times \$720{,}000/\text{week} = \$8{,}640{,}000 \\
\text{WIP value at 5 weeks LT} &= 5 \text{ weeks} \times \$720{,}000/\text{week} = \$3{,}600{,}000 \\
\text{Reduction in WIP} &= \$8{,}640{,}000 - 3{,}600{,}000 = 5{,}040{,}000 \\
\text{Annual savings} &= \$5{,}040{,}000 \times 20\% = \$1{,}008{,}000
\end{aligned}$$

Reducing cost contributes directly to profit. Increasing sales increases direct costs of labor and materials so profit does not increase in direct proportion. Materials management can reduce costs by being sure that the right materials are in the right place at the right time and the resources of the company are properly used.

There are several ways of classifying this flow of material. An often-used classification, and the one used in this text, is manufacturing planning and control and physical supply/distribution.

Manufacturing Planning and Control

Manufacturing planning and control are responsible for the planning and control of the flow of materials through the manufacturing process. The primary activities carried out are as follows:

1. **Production planning**. Production must be able to meet the demand of the marketplace. Finding the most productive way of doing so is the responsibility of production planning. It must establish correct priorities (what is needed and when) and make certain that capacity is available to meet those priorities. It involves the following activities:
   a. Forecasting.
   b. Master planning.
   c. Material requirements planning.
   d. Capacity planning.
2. **Implementation and control.** These functions are responsible for putting into action and executing the plans made by production planning. These responsibilities are accomplished through production activity control (often called *shop floor control*) and purchasing.
3. **Inventory management**. Inventories are materials and supplies carried on hand either for sale or to provide material or supplies to the production process. They are part of the planning process and provide a buffer against the differences in demand rates and production rates.

Production planning, implementation, control, and inventory management work hand-in-hand. Inventories in manufacturing are used to support production or are the result of production.

Inputs to the manufacturing planning and control system There are five basic inputs to the manufacturing planning and control system:

1. **Product description.** The product description shows how the product will appear at some stage of production. *Engineering drawings* and *specifications* are methods of describing the product. Another method, and the most important for manufacturing planning and control, is the **bill of material**. As used in materials management, the bill of material does two things:
   - Describes the components and quantities used to make the product.
   - Describes the subassemblies at various stages of manufacture.
2. **Process specifications.** Process specifications describe the steps necessary to make the assembly or end product. They are a step-by-step set of instructions describing how the product is made. This information is usually recorded on a route sheet or in a **routing**. These provide information such as the following on the manufacture of a product:
   - Operations required to make the product.
   - Sequence of operations.
   - Equipment and accessories required.
   - Standard time required to perform each operation.
3. **Time.** The time needed to perform operations is usually expressed in **standard time**, which is the time taken by an average operator, working at a normal pace, to perform a task. It is needed to schedule work through the plant, load the plant, make delivery

promises, and cost the product. Standard times for operations are usually obtained from the routing information.

4. **Available facilities.** Manufacturing planning and control must know what plant, equipment, and labor resources will be available to process work. This information is usually found in the work center information.
5. **Quantities required.** This information will come from forecasts, customer orders, orders to replace finished goods inventory, and the material requirements plan.

Physical Supply/Distribution

Physical supply/distribution includes all the activities involved in moving goods, from the supplier to the beginning of the production process, and from the end of the production process to the consumer.

The activities involved are as follows:

- Transportation.
- Distribution inventory.
- Warehousing.
- Packaging.
- Material handling.

Materials management is a balancing act. The objective is to be able to deliver what customers want, when and where they want it, and to do so at minimum cost. To achieve this objective, materials management must make tradeoffs between the level of customer service and the cost of providing that service. As a rule, costs rise as the service level increases, and materials management must find that combination of inputs to maximize service and minimize cost. For example, customer service can be improved by establishing warehouses in major markets. However, that causes extra cost in operating the warehouse and in the extra inventory carried. To some extent, these costs will be offset by potential savings in transportation costs if lower cost transportation can be used.

By grouping all those activities involved in the movement and storage of goods into one department, the firm has a better opportunity to provide maximum service at minimum cost and to increase profit. The overall concern of materials management is the balance between priority and capacity. The marketplace sets demand and materials management must plan the firm's priorities (what goods to make and when) to meet that demand. Capacity is the ability of the system to produce or deliver goods. Materials management is responsible for planning and controlling priority and capacity to meet customer demand at minimum cost.

SUMMARY

Manufacturing creates wealth by adding value to goods. To improve productivity and wealth, a company must first design efficient and effective systems for manufacturing. It must then manage these systems to make the best use of labor, capital, and material. One of the most effective ways of doing this is through the planning and control of the flow of materials into, through, and out of manufacturing. There are three elements to a material flow system: supply, manufacturing planning and control, and physical distribution. They are linked, and what happens in one system affects the others.

Traditionally, there are conflicts in the objectives of a company and in the objectives of marketing, finance, and production. The role of materials management is to balance these conflicting objectives by coordinating the flow of materials so customer service is maintained and the resources of the company are properly used.

In subsequent chapters this text will examine some of the theories and practices considered to be the fundamental body of knowledge of materials and supply chain management.

KEY TERMS

Assemble-to-order 4
Bill of material 10
Configure-to-order 3
Engineer-to-order 3
Inventory management 10
Make-to-order 3
Make-to-stock 4
Materials management 7
Metric 5
Order qualifiers 2
Order winners 2
Performance measure 5
Performance standard 6
Postponement 4
Production planning 10
Routing 10
Specification 10
Standard time 10
Supply chain 4
Work-in-process (WIP) 9

QUESTIONS

1. What is wealth, and how is it created?
2. What is value added, and how is it achieved?
3. Name and describe five major factors affecting operations management.
4. What are an order qualifier and an order winner? What is the major difference between the two?
5. Describe the five primary manufacturing strategies. How does each affect delivery lead time?
6. What must manufacturing management do to manage a process or operation? What is the major way in which management plans and controls?
7. What are the four objectives of a firm wishing to maximize profit?
8. What is the objective of marketing? What three ways will help it achieve this objective?
9. What are the objectives of finance? How can these objectives be met?
10. What are the objectives of production? How can these objectives be met?
11. Describe how the objectives of marketing, production, and finance are in conflict over customer service, disruption to production, and inventories.
12. What is the purpose of materials management?
13. Name and describe the three primary activities of manufacturing planning and control.
14. Name and describe the inputs to a manufacturing planning and control system.
15. What are the five activities involved in the physical supply/distribution system?
16. Why can materials management be considered a balancing act?
17. What are metrics? What are their uses?
18. A computer carrying case and a backpack are familiar items to a student of manufacturing planning and control. Discuss the manufacturing planning and control activities involved in producing a variety of these products. What information from other departments is necessary for manufacturing planning and control to perform its function?
19. Which manufacturing strategies are used in a fast-food business? How does this affect the lead time from the customers' point of view?
20. Give an example of a postponement activity.

PROBLEMS

1.1 If the cost of manufacturing (direct material and direct labor) is 60% of sales and profit is 10% of sales, what would be the improvement in profit if, through better planning and control, the cost of manufacturing was reduced from 60% of sales to 55% of sales?

Answer. Profits would improve by 500%.

1.2 In problem 1.1, how much would sales have to increase to provide the same increase in profits (keeping the manufacturing cost the same at 60%)?

Answer. Sales would have to increase 12.5%.

1.3 On the average, a firm has an eight-week lead time for work-in-process, and annual cost of goods sold is $16 million. Assuming that the company works 50 weeks a year:

a. What is the dollar value of the work-in-process?

b. If the lead time could be reduced to five weeks, what would be the reduction in WIP?

Answer. a. $2,560,000

b. $960,000

1.4 On the average, a company has a work-in-process lead time of 10 weeks and annual cost of goods sold of $30 million. Assuming that the company works 50 weeks a year:

a. What is the dollar value of the work-in-process?

b. If the work-in-process could be reduced to five weeks and the annual cost of carrying inventory was 20% of the WIP inventory value, what would be the annual savings?

1.5 Amalgamated Fenderdenter's sales are $10 million. The company spends $6.4 million for purchase of direct materials and $6.6 million for direct labor; overhead is $6 million and profit is $1,000,000. Direct labor and direct material vary directly with sales, but overhead does not. The company wants to double its profit.

a. By how much should the firm increase annual sales?

b. By how much should the firm decrease material costs?

c. By how much should the firm decrease labor cost?

CASE STUDY 1.1

Fran's Flowers

After Fran Fuller graduated with an undergraduate art degree in 2018, she decided to combine her knowledge and love of art with a second love—plants and flowers—toward developing a business. Her intent was to focus on a specialty niche in the flower shop business. She decided to concentrate her efforts on make-to-order special flower arrangements, like are typically found at banquets and weddings. Due to her talent and dedication to doing a good job, she was highly successful, and her business grew to where she now has a shop located in a highly visible and successful strip mall. As with many successful businesses, her success has produced unanticipated problems, some of which are normal growth pains, but others are relatively unique to the type of business. At a recent meeting with her business advisor, she outlined some of the major issues she faces:

1. **Business Focus.** When she moved into her new shop in the mall, she continued to specialize in the make-to-order specialty arrangements, but customers frequently walked into her shop requesting "spot" purchases, including gifts for sick friends and last-minute flower purchases for occasions such as birthdays, anniversaries, Valentine's Day, and so forth. As this business represented an attractive addition to the store revenue, she accommodated it with three large climate-controlled display cases stocked with ready-to-sell arrangements of various sizes, types, and costs. Even though she did not aggressively pursue this market with advertising, the heavy mall traffic where her store is located and word of mouth caused the walk-in business to steadily grow to where it now represents almost half of her total revenue. This business has brought her numerous headaches, however, due to several characteristics:

   a. Even though some days have predictably high demand (e.g., just prior to Valentine's Day, Mother's Day), most of the time she has no idea how many

customers will come in for spot buys an any given day, nor does she have any idea as to the price range they will look for. Even such variables as the weather and the schedule of local sports teams appear to affect her demand. She knows she needs to manage this demand better, because not having what a customer wants could mean the permanent loss of a good potential customer. On the other side, flowers have a limited shelf life, and having too much of the wrong price range could mean a high spoilage rate. It would not take many lost sales on a daily basis to represent the difference between profit and loss for that part of the business.

b. Some customers have become irate that her delivery system, a major part of the make-to-order business, will not accommodate the delivery of a $20 ready-to-sell arrangement to a hospital, for example. Angry customers have even asked her how much they need to spend on an arrangement before she will deliver. She has never really thought about an answer to that question and has not known how to reply. Generally, she just states that she does not deliver premade flower arrangements. She knows this lack of delivery has cost her some goodwill, some business, and perhaps even some potential return customers.

c. Related to the point above, several customers have expressed serious dissatisfaction that she is not a member of some national delivery service, so they can have flowers delivered out of town. She is afraid such a business will pull her even further from her core business of make-to-order, as those services typically focus on catalogs of set designs. As those services are also expensive to belong to, she knows she would have to spend a lot more time and effort in that area to make it financially feasible.

d. Another group of customers wants her to extend her open shop hours, as they say they occasionally drop by for flowers on their way home from work and often find her closed for the day or at least not available while she is setting up a flower order in some other location.

2. **Personnel Issues.** As her business grew, Fran hired another skilled arranger, Miguel, to work with her. The unpredictability of the walk-in demand has caused her to bring people issues up as a problem, however. As walk-in customers demand immediate attention, she and Miguel are frequently called to the front of the shop to sell arrangement from the cases. This pulls them away from working on their orders, and while they have been late only on a couple of special orders within the last few weeks, several others were delivered before she was satisfied with their appearance, merely to avoid their being late. This worries her a great deal, as she has worked very hard to obtain a reputation for the quality of her arrangements. She thought about hiring a delivery person, but decided it was important that either she or Miguel deliver the orders so that they may put last-minute touches on the arrangement in case of disturbance during the delivery process.

   Instead she opted to hire some part-time unskilled help for the shop to handle the walk-in shop sales. This has proved less than satisfactory, because of two reasons:

   a. The unpredictability of demand has her constantly wondering about what hours and how many hours to schedule the help. The extra help adds to overall cost, and paying someone to stand around while no customers come in the shop makes the difference between profit and loss even more sensitive.

   b. Customers frequently have questions about the type of flowers in an arrangement, how long they last, and so forth. The unskilled workers she hires often don't know what to answer. They will then frequently interrupt either Fran or Miguel with the question, and even when they get the answer the customer often is left with a poor impression, as they often expect more knowledge from a salesperson. The impression is even worse if both Fran and Miguel are out servicing orders, as the only answer the customer gets is "I'm not sure." Since she pays only slightly above minimum wage, her worker turnover is high. This means she is constantly trying to hire and train people, further distracting her from her main business. She knows she could reduce the turnover and hire more knowledgeable people if she paid her help

more per hour, but that issue again pushes her closer to the loss column for many of the days the shop is open, so she feels she really can't afford to pay more.

3. **Expansion.** Several of her regular customers are encouraging her to open another operation on the other side of the city, as well as considering expansion to other cities. They claim several of their friends like her arrangements a great deal, but consider her location too inconvenient from where they live or work. That is typically not a problem for large orders, as she or Miguel will typically offer to visit the customer to obtain details for the arrangement. That does take a lot of time, however, so she finds herself more frequently asking the long distance customer to come to the shop if possible. Many decline to do so, and the order is sometimes lost. While expansion is attractive to her, she worries about control—not only for order servicing, but also for delivery. How can she possibly maintain control of quality and design in two or more locations at the same time?
4. **Supply.** As her purchases of flowers from the wholesaler has grown, the wholesaler has recommended that Fran make a purchasing contract instead of making spot bulk buys as she now does. This contract will give her significant quantity price discounts, but her delivered quantity has to be above a certain amount of each type of flower so that the wholesaler can reduce costs due to economies of scale. The quantities she needs to order are reasonable given her average demand, but the fluctuation around that average is large enough to present significant spoilage during certain periods. She wonders if she would be better off in the long run with the purchasing contract.

Assignment

1. What are the key issues in this case? In other words, analyze the case to try to determine the true problems from the symptoms of those problems. How do these issues relate to the issue of strategy?
2. What type of data would you suggest collecting to both verify the problem identifications are correct and to provide solution approaches and support? How would you organize and use that data?
3. What would you suggest she do with her business and why? Provide a comprehensive and integrated plan of action and provide support for your suggestions.
4. Develop an implementation plan for whatever changes you suggest she make. Prioritize the key steps if appropriate.

CHAPTER
TWO

PRODUCTION PLANNING SYSTEM

INTRODUCTION

This chapter introduces the manufacturing planning and control (MPC) system. First, it discusses the overall system and then goes into detail on production planning. Subsequent chapters in this text discuss master scheduling, material requirements planning, capacity management, production activity control, purchasing, and forecasting.

The manufacturing of goods is complex. Some firms make a few different products, whereas others make many products. However, each uses a variety of processes, machinery, equipment, labor skills, and material. To be profitable, a firm must organize all these factors to make the right goods at the right time at top quality and do so as economically as possible. It is a complex problem, and it is essential to have a good planning and control system.

A good planning system must answer the following four questions:

1. What are we going to make or provide to customers?
2. What does it take to make it?
3. What do we already have?
4. What do we need to get?

These are questions of priority and capacity.

Priority relates to what products are needed, how many are needed, and when they are needed. The marketplace establishes the priorities. Manufacturing is responsible for devising plans to satisfy the market demand if possible. An important aspect of this is the fact that even though the market (potential customers) may demand specific quantities of specific products, the company may, and in fact should, make their plans as to what to produce based on the market demand but often significantly modified by several considerations, including:

- Existing resources, including the following:
  - People, both how many available and skill levels.
  - Equipment, both quantity and capability.
  - Funds, possibly needed to procure or change other resources.
  - Raw material availability and costs.
- Company strategy, involving several conditions, including other markets, customers, competition, and product mix.
- Possible changes in market base, including new customers, old customers leaving the market, additional competition, and possible changes in customer preferences.

Capacity is the capability of manufacturing to produce goods and services. Essentially it depends on the resources of the company—the machinery, labor, and financial resources, and the availability of material from suppliers. In the short term, capacity is the quantity of work that labor and equipment can perform in a given period. The relationship that should exist between priority and capacity is shown graphically in Figure 2.1.

In the long and short term, manufacturing must devise plans to balance the demands of the marketplace with its resources and capacity. For long-range decisions, such as the building of new plants or the purchase of new equipment, the plans must extend over a

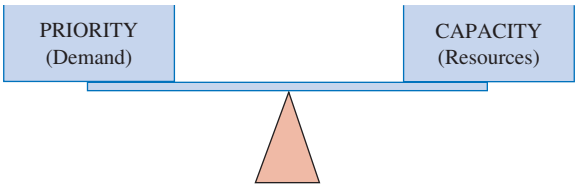

FIGURE 2.1 Priority–capacity relationship.

timeline of several years. For planning production over the next few weeks, the time span will be days or weeks. This hierarchy of planning, from long range to short range, is covered in the next section.

MANUFACTURING PLANNING AND CONTROL SYSTEM

There are five major levels in the manufacturing planning and control system:

- Strategic plan (strategy) and strategic business plan (a business plan based on the organizational strategy).
- Production plan (sales and operations plan).
- Master production schedule.
- Material requirements plan.
- Purchasing and production activity control.

Each level varies in purpose, time span, and level of detail. As the process moves from strategic planning to production activity control, the purpose changes from general direction to specific detailed planning, the time span decreases from years to days, and the level of detail increases from general categories to individual components and work centers.

Since each level is for a different time span and for different purposes, each differs in the following:

- Purpose of the plan.
- Planning horizon—the time span from now to some time in the future for which the plan is created.
- Level of detail—the detail about products required for the plan.
- Planning cycle—the frequency with which the plan is reviewed.

At each level, three questions must be answered:

1. What are the priorities—how much of what is to be produced and when?
2. What is the available capacity—what resources do we have?
3. How can differences between priorities and capacity be resolved?

Figure 2.2 shows the planning hierarchy. The first four levels are planning levels. The result of the plans is authorization to purchase or manufacture what is required. The final level is when the plans are put into action through purchasing and production activity control. Notice the arrows are pointing in two directions. This is an important issue in that it indicates that the information and planning activity goes both upward and downward. Specifically, the plan and execution levels are continually providing feedback to the planning level above it for consideration and possible modification. For example, once the production plan is developed issues of capacity, resources or demand may occur at the master schedule level that imply some evaluation and change is needed in the production plan. It is often not appropriate for a plan to be made and then not reviewed as conditions change significantly.

The following sections will examine each of the planning levels by purpose, horizon, level of detail, and planning cycle.

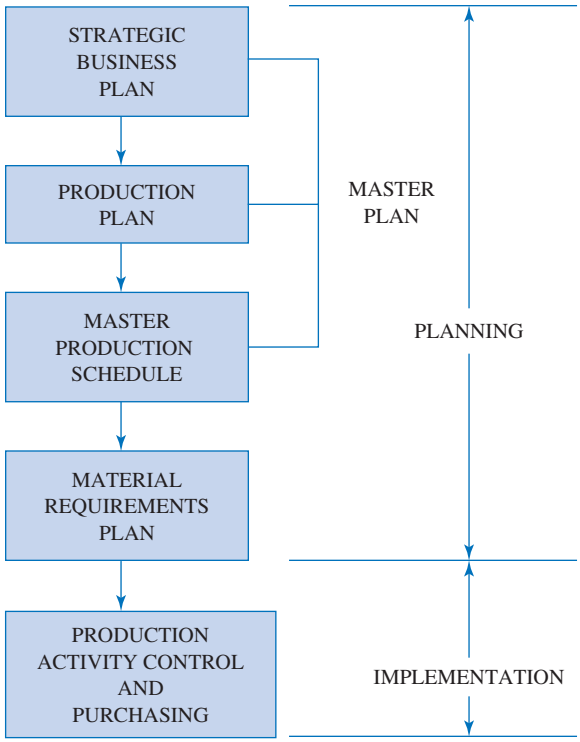

FIGURE 2.2 Manufacturing planning and control system.

The Strategic Plan

The **strategic plan** of a firm is a statement of the major goals and objectives the company expects to achieve over the next 2 to 10 years or more. It is a statement of the broad direction of the firm and shows the kind of business—product lines, markets, and so on—the firm wants to do in the future. The plan gives general direction about how the company hopes to achieve these objectives and represents a commitment to take various actions designed toward growth, defining and attracting customers, defining markets, and improving competitive and financial performance. It is based on long-range forecasts and includes participation from marketing, finance, production, engineering and all other major functions in the firm. In turn, the plan provides direction and coordination among the marketing, production, financial, engineering, and other functional plans.

Marketing and *Sales* are responsible for analyzing the marketplace and deciding the firm's response: the markets to be served, the products supplied, desired levels of customer service, pricing, promotion strategies, and so on.

Finance is responsible for deciding the sources and uses of funds available to the firm, cash flows, profits, return on investment, and budgets.

Production must satisfy the demands of the marketplace, by using plants, machinery, equipment, labor, and materials as efficiently as possible.

Engineering is responsible for research, development, and design of new products or modifications to existing ones. Engineering must work with marketing and production to produce designs for products that will sell in the marketplace and can be made most economically.

The development of the strategic plan is the responsibility of senior management. Using information from marketing, finance, production, and other functions, the strategic plan provides a framework that sets the goals and objectives for further planning by the marketing, finance, engineering, and production departments.

Some companies have adopted an approach of establishing vision statements and goals as part of the planning process. Tactical work plans are established for the visions to allow all parts of the organization to move systematically toward the overall goal.

Developed by Japanese companies, the approach is often referred to as **hoshin planning**. This approach includes the following steps:

1. Making the plan for what you wish to improve or accomplish.
2. Establishing subgoals.
3. Communicating the plan in the organization.
4. Measuring your results.
5. Analyzing data from the measures and taking corrective action as needed.
6. Repeating as necessary.

There are recent trends in business that sometimes impact the development and management of strategic plans. One of these is the issue of **sustainability**, meaning the capability to continue (sustain) operations into the long term. Much of the interest in sustainability evolved from the perspective of pollution control, saving the environment and **social responsibility** (establishing company policies that establish a positive relationship with society and strike some balance between the economy and the environment). Corporate social responsibility has become an important issue worldwide, as indicated by the **United Nations Global Compact**. This compact recognizes that business is a primary source of globalization, and the compact lays out ten principles for business strategy and operations to maintain appropriate human rights, treatment of labor, environmental issues, and anticorruption principles.

Sustainability is also based on the concepts of reduction of waste and inefficiency in production, leading not only to using fewer resources and producing less waste, but also less costs. Examples of waste reduction might include less need for packaging (often thrown away) and using resources to produce reusable outputs. Recycling and reusing material is also a major part of sustainability. Sometimes this activity is described as **remanufacturing** or **reverse logistics**. In some cases, companies will establish a formal supply chain used to retrieve a used product in order to dispose of it, reclaim materials from it, or reuse it in some fashion. This is sometimes referred to as a **reverse supply chain**. These concepts are explained in more detail in Chapters 7 (Fundamentals of Supply Chain Management) and 16 (Lean Production).

A second recent development impacting strategic planning is **risk management**. Often people consider risk to be a negative issue, and of course that is partially correct. Risks reflecting problems from some sort of failure of systems, people, or external events can result in loss of money, productivity, legal problems, and a reduction in the probability of successful implementation of the strategic plan. Risks can also be positive, and in this context are often called opportunities. Risk management is focused on establishing systems and measurements to try to quickly recognize risks and establish strategic mechanisms to minimize impacts from negative risks and take advantage of positive risks (opportunities). Risks related to supply chains will be discussed further in Chapter 7.

Effective strategic planning depends on obtaining appropriate measurements and feedback on how well the tactics related to the plan are working toward the overall set of strategic goals for the organization. These measures (both financial and nonfinancial) are sometimes referred to as **key performance indicators (KPI)**. It is important that one measure or subset of measures do not contradict with others—that they provide an overall balance in indicating the progress of the company toward the overall strategic plan and sustainability efforts including financial, societal, and environmental goals. The set of KPIs that are balanced are often referred to as a **balanced scorecard**, and detailed approaches have been developed to both establish and manage balanced scorecards. The scorecard tends to balance measures dealing with business processes, financial measures, customer focused measures, and learning and growth. All these perspectives and measures are, of course, developed as part of the overall strategic planning process.

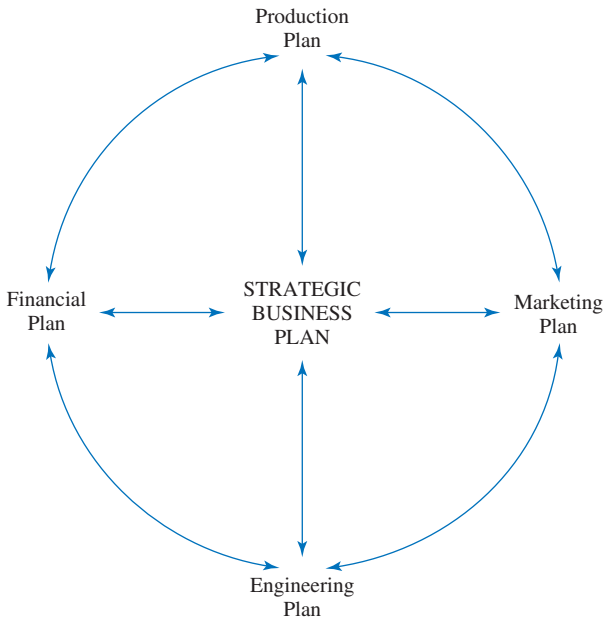

FIGURE 2.3 Business plan.

The Strategic Business Plan (Business Plan)

Once the strategic plan has been established, the plan is often restated in financial terms, including projected revenues, a projected balance sheet, and a projected income statement. This financially based plan is often called the **business plan** or sometimes the strategic business plan. Each department produces its own plans to achieve the objectives set by the strategic business plan. These plans will be coordinated with one another and with the strategic business plan. Figure 2.3 shows this relationship.

The level of detail in the strategic business plan is low. It is concerned with general market and production requirements—total market for major product groups or product families, perhaps—and not sales of individual items. It is usually stated in dollars rather than units.

Strategic business plans are usually reviewed every six months to a year.

The Production Plan

Given the objectives set by the strategic business plan, production management is concerned with the following:

- The quantities of each product group that must be produced in each period.
- The projected and desired inventory levels.
- The resources of equipment, labor, and material needed in each period.
- The availability of the resources needed.

The level of detail of the **production plan** is low. For example, if a company manufactures children's bicycles, tricycles, and scooters in various models, each with many options, the production plan will show major product groups, or families, such as bicycles, tricycles, and scooters. Because the production plan tends to combine product groups or product families rather than individual products, it is sometimes referred to as the **aggregate production plan**.

Production planners must devise a plan to satisfy market demand within the resources available to the company. This will involve determining the resources needed to meet market demand, comparing the results to the resources available, and devising a plan to balance requirements and availability.

This process of determining the resources required and comparing them with the available resources takes place at each of the planning levels and is the purpose of capacity management. For effective planning, there must be a balance between priority and capacity.

Along with the market and financial plans, the production plan is concerned with implementing the strategic business plan. The planning horizon is usually 6 to 18 months and is usually reviewed each month or quarter.

The Master Production Schedule

The **master production schedule (MPS)** is a plan for the production of individual end items. It breaks down the production plan to show, for each period, the quantity of each end item to be made. For example, it might show that 200 Model A23 scooters are to be built each week. Inputs to the MPS are the production plan, the forecast for individual end items, sales orders, inventories, and existing capacity.

The level of detail for the MPS is greater than for the production plan. Whereas the production plan was based upon families of products (e.g., tricycles), the master production schedule is developed for individual end items (each model of tricycle). The planning horizon usually extends from 3 to 18 months but primarily depends on the purchasing and manufacturing lead times. This is discussed in Chapter 3 in the section on master scheduling.The term **master scheduling** describes the process of developing a master production schedule. The term master production schedule is the end result of this process. Usually, the plans are reviewed and changed weekly or monthly, but this depends on the length of the MPS.

The Material Requirements Plan

The output of **material requirements planning (MRP)** is the **material requirements plan**, which is a plan for the production and purchase of the components used in making the items in the master production schedule. It shows the quantities needed and when manufacturing intends to make or use them. Purchasing and production activity control use MRP to execute the purchase or manufacture of specific items.

The level of detail of MRP is high. The material requirements plan establishes when the components and parts are needed to make each end item.

The planning horizon is at least as long as the combined purchase and manufacturing lead times. As with the master production schedule, it usually extends from 3 to 18 months.

Purchasing and Production Activity Control

Purchasing and **production activity control (PAC)** represent the implementation and control phase of the production planning and control system. Purchasing is responsible for establishing and controlling the flow of raw materials into the factory. PAC is responsible for planning and controlling the flow of work through the factory.

The planning horizon is very short, perhaps from a day to a month. The level of detail is high since it is concerned with individual components, work centers, and orders. Plans are reviewed and revised daily.

Figure 2.4 shows the relationship among the various planning tools, planning horizons, and levels of detail.

This chapter focuses on production planning. Later chapters deal with master scheduling, material requirements planning, purchasing and production activity control.

Capacity Management

At each level in the manufacturing planning and control system, the priority plan must be tested against the available resources and capacity of the manufacturing system. Chapter 5 describes some of the details of **capacity management**. For now, it is sufficient to understand that the basic process in capacity management is one of calculating the capacity needed to manufacture per the requirements of the priority plan and of finding methods

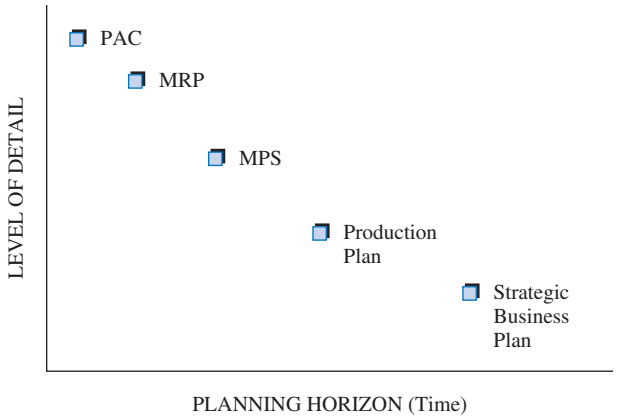

FIGURE 2.4 Level of detail versus planning horizon.

to make that capacity available. There can be no valid, workable production plan unless this is done. If the capacity cannot be made available when needed, then the plans must be changed, as inadequate resources equal missed production schedules. In addition, if resources significantly exceed what is required, they will sit idle and result in extra costs.

Determining the capacity required, comparing it to available capacity, and making adjustments (or changing plans) must occur at all levels of the manufacturing planning and control system.

Over several years, machinery, equipment, and plants can be added to or taken away from manufacturing. Some changes, such as changing the number of shifts, working overtime, subcontracting the work, and so on, can be accomplished in these time spans. However, in the time spans involved from production planning to production activity control, these kinds of large changes cannot be made.

SALES AND OPERATIONS PLANNING

The strategic business plan integrates the plans of all the departments in an organization and is normally updated annually. However, these plans should be updated as time progresses so that the latest forecasts and market and economic conditions are taken into account. **Sales and operations planning (S&OP)** is a process for continually revising the strategic business plan and coordinating plans of the various departments. S&OP is a cross-functional business plan that involves sales and marketing, product development, operations, and senior management. Operations represent supply, whereas marketing represents demand. The S&OP is the forum in which the production plan is developed.

Although the strategic plan and strategic business plan are usually updated annually, sales and operations planning is a dynamic process in which the company plans are updated on a regular basis, usually at least monthly. The process starts with the sales and marketing departments, which compare actual demand with the sales plan, assess market potential, and forecast future demand. The updated marketing plan is then reviewed with manufacturing, engineering, and finance, which adjust their plans to support the revised sales plan. If these departments find they cannot accommodate the new sales plan, then the sales plan must be adjusted. In this way the strategic business plan is continually revised throughout the year and the activities of the various departments are coordinated. Figure 2.5 shows the relationship between the strategic business plan and the sales and operations plan.

Sales and operations planning is medium range and includes the marketing, production, engineering, and finance plans. Sales and operations planning has several benefits:

- It provides a means of updating the strategic plan and the strategic business plan as conditions change.
- It provides a means of managing change. Rather than reacting to changes in market conditions or the economy after they happen, the S&OP forces management to look at the economy at least monthly and places it in a better position to plan changes.

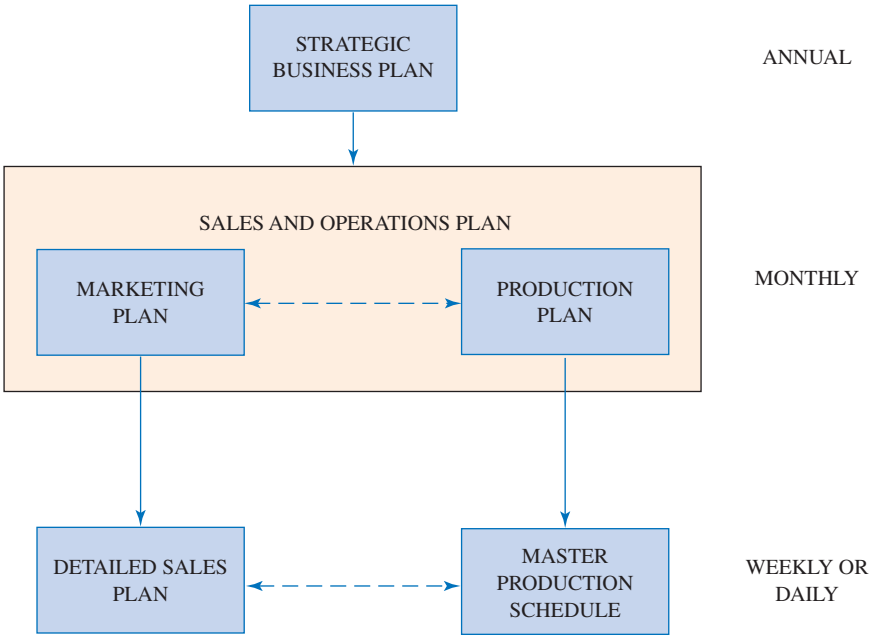

FIGURE 2.5 Sales and operations planning.

- It ensures that the various department plans are realistic and coordinated and support the business plan.
- It provides a realistic plan that can achieve the company objectives.
- It permits better management of production, inventory, and backlog (i.e., unfilled customer orders).

It is important to realize that effective sales and operations planning is an executive-level planning process that involves the potential to make significant trade-offs between the various functions/departments in the company. In this way executives involved in planning can ensure that the best approach to volume and mix are made and that supply and demand are balanced in the best approach possible.

It should be noted that the sales and operations plan does not actually schedule production, but instead focuses on producing a high-level plan for the use of company resources. These resources include not only production resources but also human resources, sales resources, financial resources, and virtually all other functions in the company. The sales and operations plan should reflect the vision and strategies developed in the strategic plan, and should serve as a focused, single plan across functional areas that provides the approach to running the entire business.

In his book *Sales and Operations Planning*, author Tom Wallace describes a five-step process in developing the S&OP, summarized here:

1. **Data gathering.** Actual past month sales, existing inventory levels, marketing/sales data, financial data, and so on.
2. **Demand planning.** Using data and other inputs from all appropriate sources to establish management forecasts. Statistical forecasts can be run, but should be evaluated in the context of other inputs. Those inputs may include new product introductions, price change impacts, competitive movements, and economic conditions. Demand planning and demand management is more fully described in Chapter 9 of this book.
3. **Supply planning.** Comparison of demand forecasts with capacity constraints.
4. **A pre-S&OP meeting.** This meeting should be used for balancing supply and demand, resolving differences (if possible), and developing action recommendations and an agenda for the top manager S&OP meeting.
5. **The executive meeting.** The final decisions are made as to how the company should proceed given all the data, recommendations, and how well the plan fits into the context of the strategic plan and the strategic business plan.

In many companies the resource discussions include some aspects of what is often called **green manufacturing**. Basically, these discussions will focus on issues such as

- Environmental impacts.
- Energy conservation.
- Material usages, such as waste reduction, reuse and recyclability.
- Scarcity of various resources.

The conclusions from these green resource discussions can help in both the design of products and process and in the most effective uses of production resources. As an example, a metal casting manufacturer in Canada, which uses a lot of electricity, schedules its melts to avoid periods of peak demand. This avoids the local energy supplier from having to increase their capacity and in turn the manufacturer is given a slightly preferred rate. It should be obvious that the concepts under the category of green manufacturing are a major part of sustainability discussed earlier in this chapter, and later in this text.

Given the fact that each level of the planning system obtains input from the level above it and also feedback from the systems below it in the hierarchy, one may be concerned that there needs to be continual evaluation and change based on something as detailed as a slight change in volume demanded from a specific customer, for example. That is not really the case, however. Referring again to Figure 2.4, notice that planning at the high levels tend to look quite far into the future, but with very little detail—and therefore need very little detail in terms of feedback from lower levels.

A brief example of a global automobile company may provide perspective. Just below the top level (overall strategic company plan) the next level planning may include general plans for an overall approach for each global region (one for Asia, another for Europe, another for North America, etc.) but do not need to project the sales of specific models, as the planning detail for the S&OP is done in product families. In the automobile company example, product families may aggregate the overall demand for SUVs as one family, overall demand for trucks as another family, overall demand for sedans as another family, and so forth. It is also possible that within each of those high-level families there can be further breakdown. Within the sedan family, for example, there could be a planning level for full-size sedans, another for compact models, and yet another for sub-compact models. At this point all the data is essentially forecast data only, since actual customer orders specify much more detail (engine size, transmission, color, options, etc.). Those specific customer order details are only captured at the master schedule level. The S&OP and other levels above the master schedule are used primarily for planning resources (type, quantity, timing, etc.). The S&OP planning level does not need to know differences in the specific details of customer orders in sedan purchases, for example, as long as the overall demand for sedans has not changed so much that it has a significant impact on resource needs to produce the sedans.

There are very practical reasons for much of this hierarchy. Typically, the development and procurement of resources (machinery, buildings, hiring and training people, for example) may take a fairly long time. The master schedule is focused on planning and delivering specific customer orders. If the type or quantity of the orders change significantly, there is usually insufficient time for the company to respond to those changes in resources needed for the order in time to meet specific customer orders. The planning for those resources should be done at the S&OP level (which needs less detail and is focused further into the future). If the S&OP is done correctly, the right resources should be available for the master schedule. If, however, a trend is observed at the master schedule level then that information needs to be communicated to the upper planning level to determine the nature of the trend and if the company needs to respond with resource allotment.

MANUFACTURING RESOURCE PLANNING

Because of the large amount of data and the number of calculations needed, the manufacturing planning and control system is usually computer-based. If a computer is not used, the time and labor required to make calculations manually is extensive and forces a company into compromises. Instead of scheduling requirements through the planning system,

the company may have to extend lead times and build inventory to compensate for the inability to schedule quickly what is needed and when.

Initially, the integrated systems were referred to as **manufacturing resource planning (MRP II)** systems. The term *MRP II* was used to distinguish the manufacturing resource planning (MRP II) from material requirements planning (MRP).

MRP II provided coordination between marketing, finance and production, with everyone agreeing on a total workable plan expressed in the production plan. Marketing and production worked together on a weekly and daily basis to adjust the plan as changes occurred. Marketing managers and production managers changed master production schedules to meet changes in forecast demand. Senior management adjusted the production plan to reflect overall changes in demand or resources, all working through MRP II. It provided the mechanism for coordinating the efforts of marketing, finance, production, and other departments in the company, as well as the effective planning of all resources of a manufacturing company.

ENTERPRISE RESOURCE PLANNING

As MRP II systems evolved, they tended to take advantage of two changing conditions:

1. Computers and information technologies (IT) becoming significantly faster, more reliable, and more powerful. People in most companies had become at least comfortable, but often very familiar, with the advantages in speed, accuracy, and capability of integrated computer-based management systems.
2. Movement toward integration of knowledge and decision making in all aspects of direct and indirect functions and areas that impact materials flow and materials management. This integration not only included internal functions such as marketing, engineering, human resources, accounting, and finance but also the upstream activities in supplier information and the downstream activities of distribution and delivery. That movement of integration is what is now recognized as supply chain management.

As the needs of the organization grew in the direction of a truly integrated approach toward materials management, the development of IT systems matched that need. As these systems became both larger in scope and integration when compared to the existing MRP and MRP II systems, they were given a new name—**enterprise resource planning (ERP)**.

ERP is similar to the MRP II system except that the whole enterprise is taken into account, not just manufacturing. The *APICS Dictionary,* 16th edition, defines ERP as a "framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage." To fully operate, there must be applications for planning, scheduling, costing, and so forth, for all layers in an organization: work centers, sites, divisions, and corporate. The larger scope of ERP systems allows the tracking of orders and other important planning and control information throughout the entire company, from procurement to ultimate customer delivery. In addition, many ERP systems are capable of allowing managers to share data between firms, meaning that these managers can potentially have visibility across the complete span of the supply chain.

Due to the power and capability of these highly integrated ERP systems being extremely high, there are some large costs involved. The large data requirements (for both quantity and accuracy) tend to make the systems expensive, and time consuming to implement. Added to the complexity is that all major areas of the company (marketing, engineering, finance, human resources, etc.) are involved and impacted by ERP, and therefore significant coordination is needed to ensure an effective implementation.

ERP is intended to be a fully integrated planning and control system that works from the top down and has feedback from the bottom up. Strategic business planning integrates the plans and activities of marketing, finance, and production to create plans intended to

achieve the overall goals of the company. In turn, master production scheduling, material requirements planning, production activity control, and purchasing are directed toward achieving the goals of the production and strategic business plans and, ultimately, the company. If priority plans have to be adjusted at any of the planning levels because of capacity problems, those changes should be reflected in the levels above. Thus, there must be feedback throughout the system.

The strategic business plan incorporates the plans of marketing, finance, and production. Marketing must agree that its plans are realistic and attainable. Finance must agree that the plans are desirable from a financial point of view, and production must agree that it can meet the required demand. The ERP system, as described here, is a master game plan for all departments in the company.

The feedback loops are quite important and as a result the overall approach is often called a "closed loop system." This implies that the higher-level planning activities are always generating plans and transmitting those plans to the lower levels for providing more detail to the plan, but simultaneously the lower levels are providing feedback to the upper-level planning systems to potentially impact both current and possible future plans.

Note the feedback (closed cycle) loops in the ERP system shown in Figure 2.6.

As the concept in supply chain grew, another planning approach was developed. Called **advanced planning and scheduling (APS)**, the approach has often included the

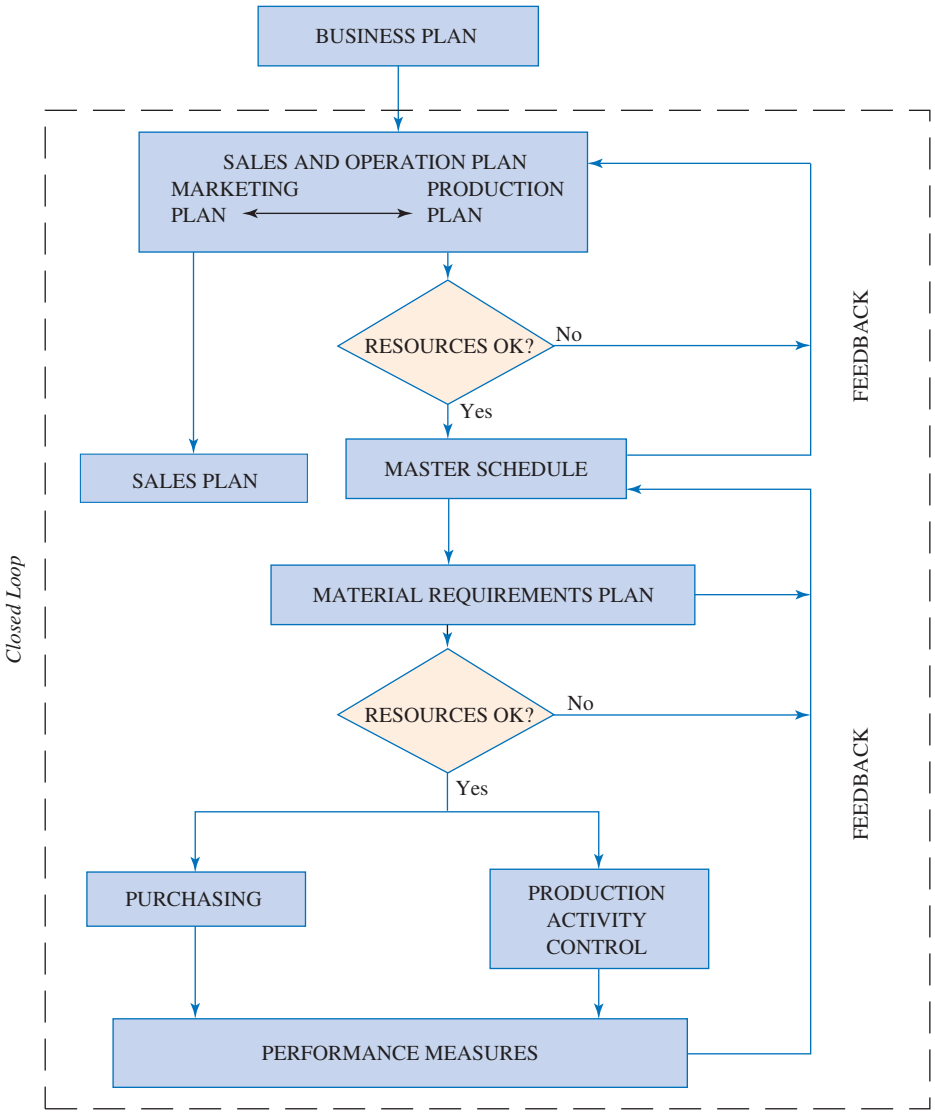

FIGURE 2.6 Enterprise resource planning (ERP).

suppliers and customers in the planning, thereby attempting to optimize the performance of the entire supply chain. The *APICS Dictionary*, 16th edition, defines APS as "any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others." Extracting information from the entire supply chain, the system attempts to create a rapid and feasible schedule for satisfying customer demand. It includes mathematical optimization and analytic tools and the principle of finite scheduling (see Chapter 6). These same concepts can also be used internally in an operation of a single company in order to try to optimize or create a more feasible solution for the customers of that operation.

MAKING THE PRODUCTION PLAN

Thus far the purpose, planning horizon, and level of detail found in a production plan have been discussed. This section includes some details involved in making production plans.

Based on the market plan and available resources, the production plan sets the limits or levels of manufacturing activity for some time in the future. It integrates the capabilities and capacity of the factory with the market and financial plans to achieve the overall business goals of the company.

The production plan is developed as part of the S&OP process and sets the general levels of production and inventories over the planning horizon. Its prime purpose is to establish production rates that will accomplish the objectives of the strategic plan and the strategic business plan. These include inventory levels, backlogs, market demand, customer service, low-cost plant operation, labor relations, and so on. The plan must extend far enough in the future to plan for the labor, equipment, facilities, and material needed to accomplish it. Typically, this is a period of 6 to 18 months and is done in quarterly, monthly, or sometimes weekly periods depending on conditions.

The planning process at this level ignores such details as individual products, colors, styles, or options. With the time spans involved and the uncertainty of demand over long periods, the detail would not be accurate or useful, and the plan would be expensive to create. For planning purposes, a common unit or small number of product groups is what is needed.

Establishing Product Groups

Firms that make a single product, or products that are similar, can measure their output directly by the number of units they produce. A brewery, for instance, might use barrels of beer as a common denominator. Many companies, however, make several different products, and a common denominator for measuring total output may be difficult or impossible to find. Product groups or families need to be established. Marketing naturally looks at products from the customers' point of view of functionality and application, whereas manufacturing looks at products in terms of processes.

Manufacturing must provide the capacity to produce the goods needed. It is concerned more with the demand for the specific kinds of capacity needed to make the products than with the demand for the product. Capacity is the ability to produce goods and services. It means having the resources available to satisfy demand. For the time span of a production plan, it can be expressed as the time available or, sometimes, as the number of units or dollars that can be produced in a given period. The demand for goods must be translated into the demand for capacity. At the production planning level, where little detail is needed, this requires identifying product groups, or families, of individual products based on the similarity of manufacturing process and resources used. For example, several computer tablets might share the same processes and need the same kind of capacity, regardless of the variations in the models. They would be considered as a family group of products.

Over the time span of the production plan, large changes in capacity are usually not possible. Additions or subtractions in plant and equipment are impossible or very difficult to accomplish in this period. However, some things can be altered, and it is the

responsibility of manufacturing management to identify and assess them. Usually the following can be varied:

- People can be hired and laid off, overtime and part time can be worked, and shifts can be added or removed.
- Inventory can be built up in slack periods and sold or used in periods of high demand.
- Work can be subcontracted or extra equipment leased.

Each alternative has its associated benefits and costs. Manufacturing management is responsible for finding the least-cost alternative consistent with the goals and objectives of the business.

Basic Strategies

In summary, the production planning problem typically has the following characteristics:

- A time horizon of 12 months or more is used, with periodic updating perhaps every month or quarter.
- Production demand consists of one or a few product families or common units.
- Demand is fluctuating or seasonal.
- Plant and equipment are fixed within the time horizon.
- A variety of management objectives are set, such as low inventories, efficient plant operation, good customer service, and good labor relations.

Figure 2.7 shows a hypothetical demand forecast for a product group. Note that the demand is seasonal.

There are three basic strategies that can be used in developing a production plan:

1. Chase strategy.
2. Production leveling.
3. Hybrid strategy.

Chase (demand matching) strategy **Chase strategy** means producing the amounts demanded at any given time. Inventory levels remain stable while production varies to meet demand. Figure 2.8 shows this strategy. The firm manufactures just enough at any one time to meet demand exactly. In some industries, this is the only strategy that can be followed. The post office must process mail over a holiday rush and in slack seasons. Restaurants have to serve meals when the customers want them. These industries cannot stockpile or inventory their products or services and must be capable of meeting demand as it occurs.

In these cases, the company must have enough capacity to be able to meet the peak demand. Farmers must have sufficient machinery and equipment to harvest in the growing

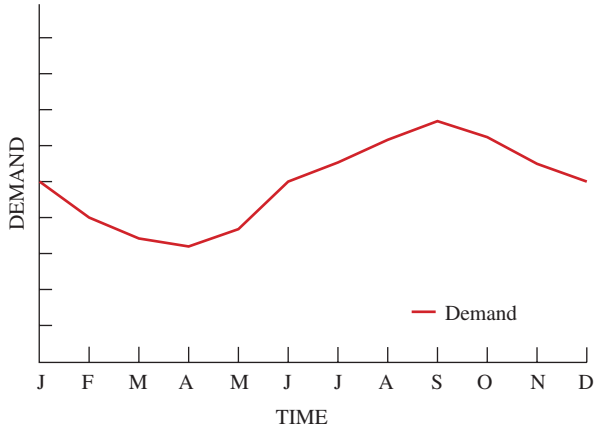

FIGURE 2.7 Hypothetical demand curve.

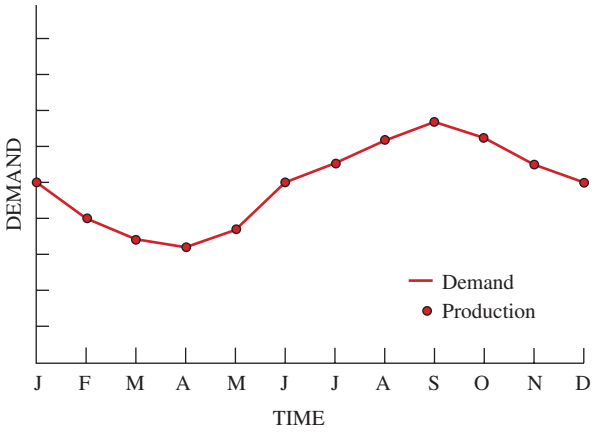

FIGURE 2.8 Chase (demand matching) strategy.

season, although the equipment will lie idle in the winter. Companies with seasonal or cyclical demand often have to hire and train people for the peak periods and lay them off when the peak is past. Sometimes they have to add extra shifts and overtime. All these changes add cost.

The advantage to the chase strategy is that inventories can be kept to a minimum. Goods are made when demand occurs and are not stockpiled. Thus, the costs associated with carrying inventories are avoided. Such costs can be quite high, as is shown in Chapter 10, on inventory fundamentals.

Production leveling **Production leveling** is continually producing an amount equal to the average demand. This relationship is shown in Figure 2.9. Companies calculate their total demand over the time span of the plan and, on the average, produce enough to meet it. Sometimes demand is less than the amount produced and an inventory builds up. At other times demand is greater and inventory is used up.

The advantage of a production leveling strategy is that it results in a smooth level of operation that avoids the costs of changing production levels. Firms do not need to have excess capacity to meet peak demand. They do not need to hire and train workers and lay them off in slack periods. They can build a stable workforce. The disadvantage is that inventory will build up in low-demand periods, which will cost money to carry. In addition, an understated forecast could result in not enough inventory being produced for the peak season.

Production leveling means the company will use its resources at a uniform rate and produce the same amount each day it is operating. The exact amount produced each month (or sometimes each week), however, will not be constant because the number of working days varies from month to month.

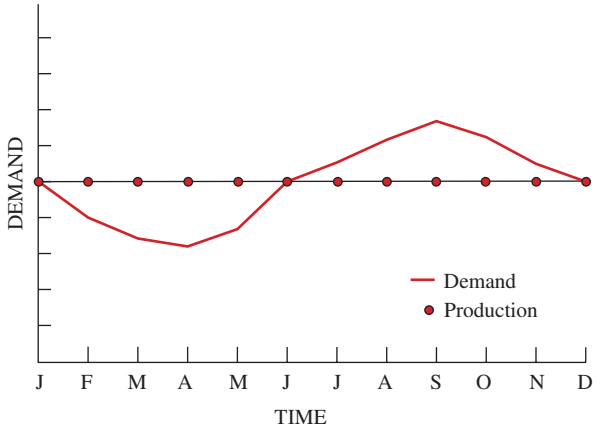

FIGURE 2.9 Production leveling strategy.

Example Problem

A company wants to produce 10,000 units of an item over the next three months at a uniform rate. Because of an annual shutdown in the third month, the first month has 20 working days; the second, 21 working days; and the third, 12 working days. On the average, how much should the company produce each day to level production?

ANSWER

$$\text{Total production} = 10{,}000 \text{ units}$$

$$\text{Total working days} = 20 + 21 + 12 = 53 \text{ days}$$

$$\text{Average daily production} = \frac{10{,}000}{53} = 188.7 \text{ units}$$

For some products for which demand is very seasonal, such as for holiday decorations, some form of production leveling strategy is necessary. The costs of idle capacity, and of hiring, training, and laying off, would be severe if a company employed a chase strategy.

As a pure strategy, production leveling would mean always producing at the defined level. Any demand above that level, assuming inventory is not available, would imply the demand would not be met or meeting the extra demand by some other method. One method already described in the discussion on chase strategy is to add people, work shifts, equipment or some combination.

Sometimes, however, conditions (e.g., no additional skilled workers available or a timing problem to add them quickly enough) imply that some other approach must be used to meet the demand. A common production choice in those cases is meeting any additional demand through **subcontracting**. Subcontracting can mean buying the extra amounts demanded from external sources. This situation is shown in Figure 2.10. The major advantage of subcontracting is internal production cost. Costs associated with excess production capacity are avoided, and because production is leveled, there are no costs associated with changing those production levels. The main disadvantage of subcontracting is that the cost of purchasing (item cost, purchasing, transportation, and inspection costs) may be greater than if the item were made internally. Subcontracting may also be used as part of a chase strategy.

An alternate choice is to purposely turn away extra demand. The latter can be done by increasing prices when demand is high or by extending lead times.

Few companies make everything or buy everything they need (this concept of make versus buy will be discussed further in Chapter 15). Subcontracting is one example of this type of decision. The decision about which items to subcontract and which to manufacture internally depends mainly on cost, but there are several other factors that may be considered.

As an example, some firms may wish to avoid subcontracting to keep confidential processes within the company, to maintain quality levels, and to maintain a workforce.

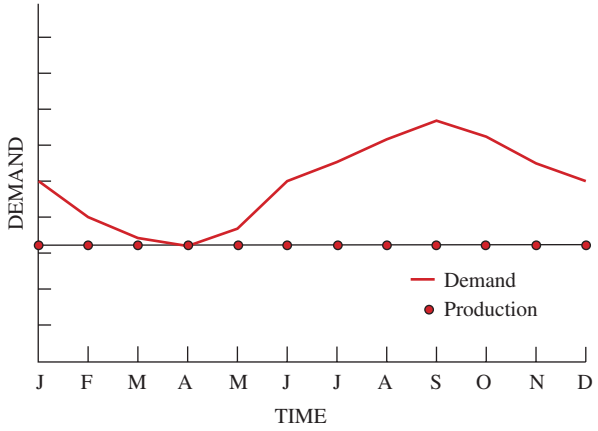

FIGURE 2.10 Subcontracting.

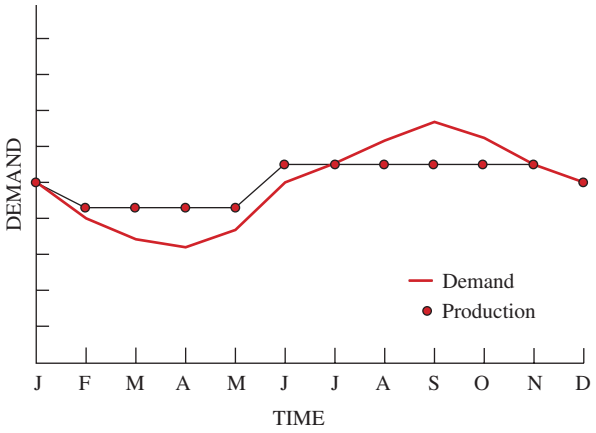

FIGURE 2.11 Hybrid strategy.

They may prefer to subcontract from a supplier who has special expertise in design and manufacture of a component, to allow the firm to concentrate on its own area of expertise, or to provide known and competitive prices. This is discussed further in Chapter 15.

For many items, such as nuts and bolts or components that the firm does not normally make, the decision is clear. For other items that are within the specialty of the firm, a decision must be made whether to subcontract or not.

Hybrid strategy The two strategies discussed so far are pure strategies. Each has its own set of costs: equipment, hiring/layoff, overtime, inventory, and subcontracting. In reality, there are many possible hybrid or combined strategies a company may use. Each will have its own set of cost characteristics. Production management is responsible for finding the combination of strategies that minimizes the sum of all costs involved, providing the level of service required, and meeting the objectives of the financial and marketing plans.

Figure 2.11 shows a possible **hybrid strategy** plan. Demand is matched to some extent, production is partially smoothed, and in the peak period some subcontracting takes place. The plan is only one of many that could be developed.

Developing a Make-to-Stock Production Plan

In a **make-to-stock** environment, products are made and put into inventory before an order is received from a customer. Sale and delivery of the goods are made from inventory. Off-the-rack clothing, frozen foods, and bicycles are examples of this kind of manufacturing.

Generally firms make to stock when

- Demand is fairly constant and predictable.
- There are few product options.
- Delivery times demanded by the marketplace are much shorter than the time needed to make the product.
- Product has a long shelf life.

The information needed to make a production plan is as follows:

- Forecast by period for the planning horizon.
- Opening inventory.
- Desired ending inventory.
- Any past-due customer orders. These are orders that are late for delivery and are sometimes called **backorders**. Note the difference between the terms backorders and backlogs (mentioned earlier in the chapter). The backlog is customer orders received but not yet shipped, while the backorders are customer orders that may be past due or due for immediate shipment but cannot because the inventory levels are too low to fill the order.

The objective in developing a production plan is to minimize the costs of carrying inventory, changing production levels, and stocking out (not having the products the customer wants when they are wanted).

The following sections develop a plan for leveling production and one for chase strategy.

Level production plan Following is the general procedure for developing a plan for level production.

1. Total the forecast demand for the planning horizon.
2. Determine the opening inventory and the desired ending inventory.
3. Calculate the total production required as follows:

$$\text{Total production} = \text{Total forecast} + \text{back orders} + \text{ending inventory} - \text{opening inventory}$$

4. Calculate the production required each period by dividing the total production by the number of periods.
5. Calculate the ending inventory for each period.

Example Problem

Amalgamated Fish Sinkers makes a product group of fresh fish sinkers and wants to develop a production plan for them. The expected opening inventory is 100 cases, and the company wants to reduce that to 80 cases by the end of the planning period. The number of working days is the same for each period. There are no backorders. The expected demand for the fish sinkers is as follows:

Period	1	2	3	4	5	Total
Forecast (cases)	110	120	130	120	120	600

a. How much should be produced each period?

b. What is the ending inventory for each period?

c. If the cost of carrying inventory is $5 per case per period based on ending inventory, what is the total cost of carrying inventory?

d. What will be the total cost of the plan?

ANSWER

a. $\text{Total production required} = 600 + 80 - 100 = 580 \text{ cases}$

$$\text{Production each period} = \frac{580}{5} = 116 \text{ cases}$$

b. $\text{Ending inventory} = \text{opening inventory} + \text{production} - \text{demand}$

$$\text{Ending inventory after the first period} = 100 + 116 - 110 = 106 \text{ cases}$$

Similarly, the ending inventories for each period are calculated as shown in Figure 2.12. The ending inventory for period 1 becomes the opening inventory for period 2:

$$\text{Ending inventory (period 2)} = 106 + 116 - 120 = 102 \text{ cases}$$

Period		1	2	3	4	5	Total
Forecast (cases)		110	120	130	120	120	600
Production		116	116	116	116	116	580
Ending Inventory	100	106	102	88	84	80	

FIGURE 2.12 Level production plan: Make-to-stock.

Period	0	1	2	3	4	5	Total
Demand (cases)		110	120	130	120	120	600
Production	100	90	120	130	120	120	580
Change in Production		10	30	10	10	0	60
Ending Inventory	100	80	80	80	80	80	

FIGURE 2.13 Chase strategy: Make-to-stock.

c. The total cost of carrying inventory would be

$$(106 + 102 + 88 + 84 + 80)\ \$5 = \$2300$$

d. Since there were no stockouts and no changes in the level of production, this would be the total cost of the plan.

Chase strategy Amalgamated Fish Sinkers makes another line of product called fish stinkers. Unfortunately, they are perishable, and the company cannot build inventory for sale later. They must use a chase strategy and make only enough to satisfy demand in each period. Inventory costs will be a minimum, and there should be no stockout costs. However, there will be costs associated with changing production levels.

Suppose in the preceding example that changing the production level by one case costs $20. For example, a change from 50 to 60 would cost

$$(60 - 50) \times \$20 = \$200$$

The opening inventory is 100 cases, and the company wishes to bring this down to 80 cases in the first period. The required production in the first period would then be

$$110 - (100 - 80) = 90 \text{ cases}$$

Assuming that production in the period before period 1 was 100 cases, Figure 2.13 shows the changes in production levels and in ending inventory.

The cost of the plan would be as follows:

$$\text{Cost of changing production level} = (60)\$20 = \$1200$$

$$\text{Cost of carrying inventory} = (80 \text{ cases})(5 \text{ periods})\$5 = \$2000$$

$$\text{Total cost of the plan} = \$1200 + \$2000 = \$3200$$

It should be noted that the previous examples provide a basic understanding of the dollar cost of possible production plans. But before a final selection of a plan is made, there are other considerations that should be evaluated, and some of those are difficult to estimate financially. Some of those issues might include the following:

- Impact on customers if cyclical demand in a level schedule causes shortages.
- Impact on production workers as they are moved into and out of production in a chase strategy. Such an impact will often reduce efficiency of the operation.
- Potential loss of profit if customers change buying preferences and seek a competitor's products.

Developing a Make-to-Order Production Plan

In a **make-to-order** environment, manufacturers wait until an order is received from a customer before starting to make the goods. Examples of this kind of manufacture are custom-tailored clothing, custom furniture, or any product made to customer specification. Very expensive items are usually made to order. Generally, firms make to order when

- Goods are produced to customer specification.
- The customer is willing to wait while the order is being made.
- Generally, the product is expensive to make and to store.
- Several product options are offered.

Assemble-to-order Where several product options exist, such as in automobiles, and where the customer is not willing to wait until the product is made, manufacturers produce and stock standard component parts. When manufacturers receive an order from a customer, they assemble the component parts from inventory according to the order. Since the components are stocked, the firm only needs time to assemble before delivering to the customer. Examples of assemble-to-order products include automobiles and computers. **Assemble-to-order** is a subset of make-to-order.

The following information is needed to make a production plan for make-to-order products:

- Forecast by period for the planning horizon.
- Opening backlog of customer orders.
- Desired ending backlog.

Backlog In a make-to-order environment, a company does not build an inventory of finished goods. Instead, it has a **backlog** of unfilled customer orders. The backlog normally will be for delivery in the future and does not represent orders that are late or past due. A custom woodwork shop might have orders from customers that will keep it busy for several weeks. This will be its backlog. If individuals want some work done, the order will join the queue or backlog. Manufacturers like to control the backlog so that they can provide a good level of customer service.

Level production plan Following is a general procedure for developing a make-to-order level production plan:

1. Total the forecast demand for the planning horizon.
2. Determine the opening backlog and the desired ending backlog.
3. Calculate the total production required as follows:

   $$\text{Total production} = \text{total forecast} + \text{opening backlog} - \text{ending backlog}$$

4. Calculate the production required each period by dividing the total production by the number of periods.
5. Spread the existing backlog over the planning horizon according to due date per period.

Example Problem

A local printing company provides a custom printing service. Since each job is different, demand is forecast in hours per week. Over the next five weeks, the company expects that demand will be 100 hours per week. There is an existing backlog of 100 hours, and at the end of five weeks, the company wants to reduce that to 80 hours. How many hours of work will be needed each week to reduce the backlog? What will be the backlog at the end of each week?

ANSWER

$$\text{Total production} = 500 + 100 - 80 = 520 \text{ hours}$$

$$\text{Weekly production} = \frac{520}{5} = 104 \text{ hours}$$

The backlog for each week can be calculated as

$$\text{Projected backlog} = \text{old backlog} + \text{forecast} - \text{production}$$

$$\text{For week 1: Projected backlog} = 100 + 100 - 104 = 96 \text{ hours}$$

$$\text{For week 2: Projected backlog} = 96 + 100 - 104 = 92 \text{ hours}$$

Figure 2.14 shows the resulting production plan.

Period		1	2	3	4	5	Total
Sales Forecast		100	100	100	100	100	500
Planned Production		104	104	104	104	104	520
Projected Backlog	100	96	92	88	84	80	

FIGURE 2.14 Level production plan: Make-to-order.

Product	Wood (board feet)	Labor (standard hours)
Tables	20	1.31
Chairs	10	0.85
Stools	5	0.55

FIGURE 2.15 Resource bill.

Resource Planning

Once the preliminary production plan is established, it must be compared to the existing resources of the company. This step is called resource requirements planning or **resource planning**. Two questions must be answered:

1. Are the resources available to meet the production plan?
2. If not, how will the difference be reconciled?

If enough capacity to meet the production plan cannot be made available, the plan must be changed.

A tool often used is the **resource bill**. This shows the quantity of *critical* resources (materials, labor, and bottleneck operations) needed to make one average unit of the product group. Figure 2.15 shows an example of a resource bill for a company that makes tables, chairs, and stools as a three-product family.

If the firm planned to make 500 tables, 300 chairs, and 1500 stools in a particular period, they could calculate the quantity of wood and labor that will be needed. For example, the amount of wood needed is

$$\begin{aligned} \text{Tables}: \quad & 500 \times 20 = 10{,}000 \text{ board feet} \\ \text{Chairs}: \quad & 300 \times 10 = 3000 \text{ board feet} \\ \text{Stools}: \quad & 1500 \times 5 = 7500 \text{ board feet} \\ \text{Total wood required} \quad & = 20{,}500 \text{ board feet} \end{aligned}$$

The amount of labor needed is

$$\begin{aligned} \text{Tables}: \quad & 500 \times 1.31 = 655 \text{ standard hours} \\ \text{Chairs}: \quad & 300 \times 0.85 = 255 \text{ standard hours} \\ \text{Stools}: \quad & 1500 \times 0.55 = 825 \text{ standard hours} \\ \text{Total labor required} \quad & = 1735 \text{ standard hours} \end{aligned}$$

The company must now compare the requirements for wood and labor with the availability of these resources. For instance, suppose the labor normally available in this period is 1600 hours. The priority plan requires 1735 hours, a difference of 135 hours, or about 8.4%. Extra capacity must be found, or the priority plan must be adjusted. In this example, it might be possible to work overtime to provide the extra capacity required. If overtime is not possible, the plan must be adjusted to reduce the labor needed. This might involve shifting some production to an earlier period or delaying shipments.

SUMMARY

Production planning is the first step in a manufacturing planning and control system and is often accomplished through the use of sales and operations planning, which is an executive-level planning process involving trade-offs across departments or functions in the company. The planning horizon usually extends for at least a year. The minimum horizon depends on the lead times to purchase materials and make the product. The level of detail is low. Usually, the plan is made for families of products based on the similarity of manufacturing processes or on some common unit. Most hierarchical planning also is "closed loop," in that it provides not only upper-level plans to drive the lower level detailed planning, but also incorporates feedback information from the lower-level planning activities in order to make all the plans more coordinated and effective.

Three basic strategies can be used to develop a production plan: chase, leveling production, or hybrid. Each has its operational and cost advantages and disadvantages. It is the responsibility of manufacturing management to select the best combination of these basic plans so total costs are minimized and customer service levels are maintained.

A make-to-stock production plan determines how much to produce in each period to meet the following objectives:

- Achieve the forecast.
- Maintain the required inventory levels.

Although demand must be satisfied, the plan must balance the costs of maintaining inventory with the cost of changing production levels.

A make-to-order production plan determines how much to produce in each period to meet the following objectives:

- Achieve the forecast.
- Maintain the planned backlog.

The cost of a backlog that is too large equals the cost of turning away business. If customers have to wait too long for delivery, they might take their business elsewhere. As with a make-to-stock production plan, demand must be satisfied, and the plan must balance the costs of changing production levels with the cost of a backlog that is larger than desired.

KEY TERMS

Advanced planning and scheduling (APS) 26
Aggregate production plan 20
Assemble-to-order 34
Backlog 34
Backorder 31
Balanced scorecard 19
Business plan 20
Capacity 16
Capacity management 21
Chase strategy 28
Enterprise resource planning (ERP) 25