THIRD EDITION

APICS
OPERATIONS MANAGEMENT BODY OF KNOWLEDGE FRAMEWORK

APICS FOUNDATION

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Third Edition

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Preface

In 2007 and 2008, the members of the APICS Body of Knowledge Professional Development Committee, the Operations Management Body of Knowledge Subcommittee, and generous volunteers laid the groundwork for the first edition of the *APICS Operations Management Body of Knowledge (OMBOK) Framework*. Their shared goal was to create a high-level document outlining the scope of the field of operations and supply chain management—a reference guide for the profession.

The *APICS OMBOK Framework* can be read from cover to cover or in individual sections. Each topic stands alone; but in sum, they represent operations management as a professional discipline and a field of study. The document is not intended as a study aid or replacement for certification exam preparation materials. It is, as its title suggests, a framework for the body of knowledge that APICS The Association for Operations Management is committed to impart to its members, customers, and partners for the betterment of the field of operations and supply chain management.

When the first edition of the *APICS OMBOK Framework* was released, it was the first work of its kind. The second edition, released in 2009, included a set of appendices compiled from the results of a pair of surveys of operations and supply chain management professionals, as well as professionals in the non-manufacturing industries of distribution, health care, retail, utilities, and hospitality. The mapping of these job functions to relevant *APICS OMBOK Framework* topics expanded the reach of the document and provided real-world applicability. A comprehensive index also was added, codifying the concepts and terms of the document and making it more accessible.

The field of operations and supply chain management is changing constantly, and APICS is committed to evolving the profession and keeping its members and customers current. To that end, the third edition of the *APICS OMBOK Framework* contains expanded sections on sustainability and risk management. This edition also includes other features for easier reading, including an updated index and alignment with the *APICS Dictionary*, 13th Edition.

As operations and supply chain management continues to evolve, the *APICS OMBOK Framework* will continue to be revised and updated to match the new knowledge and trends developed by practitioners on the leading edges of the field.

Preface

It is my heartfelt pleasure to introduce the third edition of the *APICS Operations Management Body of Knowledge (OMBOK) Framework*. In the years since its first publication, the *APICS OMBOK Framework* has created a standard for the scope of knowledge of the field of operations and supply chain management. But there still is a journey ahead of us.

We must continue our work to raise the level of awareness of the operations and supply chain management topics that comprise the *APICS OMBOK Framework*. I hope that many of you share in my vision that someday, we will raise the level of general understanding of our field and it will be recognized as a profession on a par with accountant or architect. To accomplish this, there must be a strong understanding of the scope of the field and what needs to be known to be considered an expert. The *APICS OMBOK Framework* goes a long way toward defining this scope.

In the third edition, we expanded on the two major topics of sustainability and risk management. Sustainability relates to the impact our decisions have on people and the planet. The idea that profit alone should dominate a firm's decisions has given way to the expanded view that the fragile resources of our world need to be preserved and fair labor practices need to be used. All operations and supply chain professionals should recognize these norms.

Risk management addresses the mitigation of the threats inherent in supply chains. Many of the most popular cost-saving ideas also are the most risky. In methodologies such as lean management, where inventory in supply chains is minimized, the risk associated with disruptions potentially increases. Similarly, there may be increased risk associated with global versus single sourcing and using distribution hubs. When making these types of decisions, business leaders must evaluate from a risk perspective. They must assess potential impacts and enact risk mitigation strategies.

We look forward to learning your thoughts about the third edition of the *APICS OMBOK Framework*. Please feel free to take a moment and complete the feedback form at the end of this document. What should be expanded on or added in the future? We are not looking for buzzwords or ideas that are only applicable to a specific industry; rather, we seek fundamental concepts that can be used to create real value within our supply chains. Your ideas will help shape the structure of the *APICS OMBOK Framework* in the years to come.

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CHAPTER 1

Introduction

1.1 Purpose of the *APICS OMBOK Framework*

The *APICS Operations Management Body of Knowledge (OMBOK) Framework* provides an outline of the areas of knowledge required to manage the processes for producing and delivering common products and services. The descriptions give an overview of each area and, when taken together, define a generally accepted view of the scope of operations management as a field of study. As operations management is a dynamic field, the framework will evolve over time to reflect changing perceptions and incorporate new approaches as their usage becomes prevalent.

1.1.1 Scope of operations management

Operations management focuses on the systematic direction of the processes involved in the sourcing, production, and delivery of products and services. It calls for a holistic or systems view of the processes with major impact on the costs required to operate a firm. It assumes that many technical aspects of operation, particularly details related to engineering, are handled by specialists. Operations management concepts apply to the complete chain of activities in the production and delivery of products and services, including those that cross commercial and geographical boundaries. These concepts also are applicable to non-operations fields such as marketing, finance, and information technology, although this is not the primary focus of this document.

1.1.2 Taxonomy of major concepts and tools

The *APICS OMBOK Framework* includes only the basic concepts and tools that are in common use. Concepts and tools that are starting to enter common usage may be listed as emerging operations technologies. (See Chapter 9.) Additionally, some concepts, tools, and techniques used in specific areas or industries may only be noted tangentially.

1.1.3 A systems view of the components of operations management

Manufacturing products and delivering services involve a complex series of transformational processes. Operations management coordinates these individual processes. Management decisions generally consist of long-range strategic, intermediate-term tactical, and short-term operational and control decisions. The long-range strategic decisions typically are the focus of high-level operations executives while the intermediate- and short-term operations decisions relate to mid- and entry-level line and staff functions within a firm.

1.2 Organization of the *APICS OMBOK Framework*

The *APICS OMBOK Framework* is a high-level publication representing the areas of concern for the typical operations management professional. It is a convenient way to view the scope of field, but it is not intended to be an replacement for operations management courses or certification exams. Educational pedagogy dictates that these topics be covered in different ways depending on specific objectives.

1.2.1 Level of coverage

The *APICS OMBOK Framework* is a high-level document that codifies the specific elements of operations management. It is not intended as a list of recommended best practices or an instructional training guide. Its structure enables greater depth of coverage in areas of particular relevance to operations management. It builds upon the foundational information in the *APICS Dictionary* and other preexisting bodies of knowledge. In some cases, the *APICS OMBOK Framework* references these sources directly.

1.2.2 Update schedule and process

The *APICS OMBOK Framework* is maintained and improved through the APICS Body of Knowledge Committee. This committee administers the process of regularly polling subject matter experts across industries, functions, and geographies to identify emerging areas for inclusion in the *APICS OMBOK Framework* and to identify areas of reduced relevance to be considered for reduced emphasis or removal. Where appropriate, the committee may designate subgroups or other professional societies to lead the maintenance and improvement of subsections of the *APICS OMBOK Framework*.

1.3 Overview of APICS certification

1.3.1 Rationale for operations management certification programs

From its inception in 1957, APICS intended to provide the means by which its members could demonstrate that theirs was a profession fully on a par with engineering, accountancy, and other functional callings. It appointed a Curricula and Certification (C&C) Council in the late 1960s to identify the body of knowledge that represented production and inventory management. This council did not aspire to establish a licensing credential, but to demonstrate the deeply specialized expertise required to execute materials management functions. These initial efforts began long before computers became common in the workplace, so many of the competencies identified required a significant understanding of complicated mathematical functions and their application to the daily management of operations.

Within a few years, the C&C Council was administering examinations on a regular basis around the world, and through the Certified in Production and Inventory Management credential, earned by successfully passing four examinations, designees gained the recognition and respect of their peers in other manufacturing professions. Two additional certification programs followed: Certified in Integrated Resource Management in 1991 and Certified Supply Chain Professional in 2006. For each of the three programs, a unique body of knowledge was identified and developed.

For certified individuals in any or all of the three programs, the credentials demonstrate their commitment to acquiring current industry knowledge and achieving continual improvement.

.1 Certified in Production and Inventory Management (CPIM)

The first two certification examinations were developed on the topics of inventory management and forecasting, closely followed by shop floor control and material requirements planning. Over time, additional modules were created and incorporated. The current CPIM structure integrates those modules and consists of the entry level exam on Basics of Supply Chain Management; three pillars of knowledge entitled Master Planning of Resources, Detailed Scheduling and Planning, and Execution and Control of Operations; and the capstone exam on Strategic Management of Resources.

.2 Certified in Integrated Resource Management (CIRM)

The CIRM program was developed to identify a number of key functions that make up a business enterprise and to examine the way these functions interact, particularly when enterprise-wide activities require them to collaborate on a project. The CIRM materials explored the internal drivers and issues of each function and the ways those issues might conflict with other needs and interests, and suggested methods by which project managers or team leaders might deal with the resulting territorial disputes. CIRM primarily focused on business strategies and problem solving for middle managers working with diverse, cross-functional teams. The last CIRM examination was given in April 2008.

.3 Certified Supply Chain Professional (CSCP)

The CSCP program was developed to assist candidates in internalizing their connections to the "supplier's supplier" and the "customer's customer." Rather than being seen as a discrete entity, the enterprise is viewed as a link in a supply chain that crosses organizations and, in some cases, oceans and continents. This picture of a company's place in the broader scheme requires global thinking by managers struggling with outsourcing and international distribution networks.

The supply chain is a fragile, dynamic entity and managing its various links requires a broad understanding of its unique constraints. Procurement, manufacturing, and logistics, among other disciplines, all are woven together by technology. Speed to the market is enabled by the real-time exchange of information among widely separated partners. Demystifying these complex relationships is the goal of the CSCP educational program.

1.3.2 Certification processes, including maintenance

Originally, APICS certifications were attained through individual study of the core principles of operations management. Subject matter experts annually prepared outlines of the principles and techniques that qualified certification candidates were expected to understand. From its first quantification, the APICS body of knowledge was a dynamic entity. Not only did the original curriculum outlines expand into new areas, but emerging technologies were monitored for viability and were eventually broadened into curricula of their own. As industry best practices changed, the existing production and inventory management body of knowledge was adapted to reflect them.

Certification candidates can prepare for examinations in many ways. Experience is a significant factor, and what was once entirely a self-study regimen has been expanded to include instructor-led classroom instruction, online courses, and study groups.

Each certification program has a separate structure. The CPIM designation currently requires five examinations, although over its lifetime the requirement has varied from four to seven tests. The CIRM program required four examinations on core principles followed by a fifth, capstone examination assimilating the core principles into an organized, strategic vision. The CSCP credential requires completion of an initial eligibility application and is awarded by passing a single examination.

Both the CPIM and CSCP designations incorporate a maintenance cycle. After five years, certified individuals are required to demonstrate their continued growth within the profession by performing activities such as attending educational events and classes, teaching topics within the body of knowledge, or contributing to the development of the APICS body of knowledge and supporting the mission of APICS.

APICS certification programs represent the culmination of the APICS body of knowledge and serve to keep it robust.

1.4 Relevance of operations management

1.4.1 Across business functional sectors

Components of operations management are applicable to almost every type of enterprise, from manufacturing to service organizations. Businesses that rely on the processes and control delivered by operations management include manufacturers, banks and financial organizations, retailers and distributors, utility companies, schools and universities, health care providers and hospitals, nonprofit organizations, and government agencies.

1.4.2 Global boundaries

In the global economy, operations management has become borderless as it touches on processes that span supply chains around the world. Global sourcing requires collaborative global planning, and the extended supply chain requires global logistics planning and execution. Knowledge of other nations' laws, customs, and business practices is of growing importance in operations management.

1.4.3 Current issues in operations management

The following issues are among those being addressed by progressive operations management professionals today.

Globalization. Globalization, understood from economic, financial, accounting, human resources, marketing, cultural, and other perspectives, has brought new challenges to operations management as corporations extend their supply chains beyond their national borders and deal with suppliers and customers around the world.

Information technology (IT). IT is changing rapidly and is providing new and better ways to facilitate the planning and control of a corporation's activities. Continual development in technology is creating tighter connections in the supply chain, fostering collaboration between partners, improving the ability to plan and schedule, and increasing productivity within a corporation and its supply chains.

Time-based competition. The ability to deliver products and services to the market quicker than competitors has become an advantage in markets where low price and high quality have ceased to be market differentiators.

Innovative business models. As market conditions continue to shift and evolve, some corporations are changing their business models to gain competitive advantage. These changes often include modification of the physical or financial flows associated with delivering products and services, often enabled by emerging technologies. Examples of new business models enabled by the rise of the internet include Amazon (selling directly to consumers), eBay (connecting willing buyers directly to willing sellers), and Dell (reducing inventory dynamically in a build-to-order environment). Operations management professionals should understand these changing models and their applicability in various markets.

Sustainability. Sustainability refers to a corporation's processes, products, and services being aligned in a way that is socially, economically, and environmentally responsible. Operations management can contribute to good corporate practices by controlling the inputs, outputs, and technologies used in the transformation process. (See section 2.3.)

Collaborative work. Outsourcing and elongated supply chains (supply chains with multiple partners over long distances) necessitate greater collaboration between partners. This collaboration is enhanced by technology that connects partners and shares information between them in real time.

Organizational development. Innovation and collaboration with supply chain partners requires corporations to identify and align internal and external organizational processes. By seeking to understand the reasons organizations and individuals resist change, organizational development proactively guides the transformation needed to enhance alignment within the organization and throughout every link of the supply chain.

CHAPTER 2

Strategy

2.1 Operations strategy

The focus of operations strategy in an organization is to understand and achieve the ability to consistently deliver products and services to meet customer needs and the business's overall plans. Objectives typically focus on the areas of quality, cost, flexibility, and speed. Operations strategy corresponds to the overall business strategy, especially as it relates to meeting customer needs and the market direction of procurement, conversion, and delivery of products and services. Operations strategy must be consistent with the firm's functional strategies, including those of marketing and finance.

2.1.1 Transformation processes

Manufacturing, service, and supply chain transformation processes use resources to convert inputs into some desired output. Inputs can be a raw material, a customer, or a finished product from another system. Transformation processes include, but are not limited to, the following categories.

Physical. Manufacturing processes, for example, are where physical material is converted to finished products.

Location. Transportation of a product is an example of a location transformation. These are common in supply chains and also in factories and warehouses.

Exchange. An example is found in retail, where a customer exchanges money for an item.

Storage and redistribution. These are processes where an item is stored and made available for immediate delivery, for example, in a warehouse or distribution center.

Physiological. An example of this type of transformation process is a hospital, where sick patients are the inputs and healthy patients are the desired outputs.

Informational. Informational processes are where data is stored, transferred, analyzed, and made available for various purposes.

2.1.2 Competitive priorities

Operational competitive priorities often are devised to create advantages in the marketplace. These priorities are driven by business plan objectives and customer preferences of products and services. Typically the top drivers include high quality, low cost, and high customer service through convenience, speed, and flexibility.

2.1.3 Order winners and order qualifiers

These are product or service highlights seen as valuable by the customer. Order qualifiers are screening criteria that must be fulfilled before a firm's products or services can even be considered as possible candidates for purchase. Order winners are unique characteristics or combinations of characteristics that result in a competitive advantage and obtaining (winning) an order from the customer.

2.1.4 Activity-system maps

Activity-system maps are diagrams showing how a company's strategy is delivered through a set of tailored activities. They help the major operational processes of the firm align with operational priorities. Competitive advantage stems from the way the firm's activities reinforce one another.

2.1.5 Operations alignment with corporate strategy and the supply chain

Execution of operations strategy is critical to the execution of business goals. The business plan typically is focused on financial objectives, market and product objectives, technology, and growth. Operations must align these goals with processes such as speed, flexibility, cost and quality. Typically, trade-offs must be considered, such as speed of delivery versus cost.

2.1.6 Economies of scale/economies of scope

Large companies can take advantage of economies of scale due to their ability to spread significant investments in resources, such as plants and equipment, over larger volumes of finished goods and services, lowering the incremental portion of cost over higher-volume production. When higher volumes are not necessarily the same items but share common resources, combined production creates economies of scope. For example, larger organizations often have more negotiating power with their suppliers, and third-party logistics organizations often have better success negotiating freight costs than smaller manufacturers.

2.1.7 Considerations in adding capacity

Important factors to consider when adding capacity include maintaining system balance, frequency of capacity additions, and the use of external capacity. In a perfectly balanced system, the output of each stage matches the input of the next stage, in such areas as movement of material in a plant, flows from suppliers to plants through distribution centers to customers, and service calls processing from a call center. In practice, it often is difficult to maintain this system balance, and sometimes it is even undesirable. Ways of dealing with imbalance include scheduling temporary downtime, scheduling overtime, leasing equipment, and subcontracting.

When dealing with the frequency of capacity additions, it is important to consider the costs of large versus small chunks of capacity, and the cost of excess capacity that is carried as overhead until used.

2.1.8 Understanding constraints

Constraints management centers on understanding the weakest link in the process flow—typically the link with the least capacity or the bottleneck operation. This relates to both internal processes and the supply chain. From a strategy standpoint, constraints often impact the ability to reach customer service goals, pricing targets, and quality expectations.

2.1.9 Sustainability, ethics, and social responsibility

Business requires trust and integrity between partners in the supply chain. Sustainability relates to the degree of concern for the environment, including use of renewable resources and minimization of harmful waste.

Ethics relates to alignment with legal and moral codes of conduct in all activities of the firm. This can be particularly challenging in a global company, as legal and moral codes may differ significantly across cultures and geographies. In some cases there may be prescribed processes to help ensure ethical dealings, such as those embodied in the Sarbanes-Oxley act of 2002 in the United States.

Social responsibility relates to the areas of sustainability and ethics as they pertain to the communities where the organization does business. It further extends into how the organization supports its communities and encourages its workers to follow suit. (See section 2.3.)

2.1.10 Operations metrics

Operations metrics are a quantitative indicator for process change, showing improving, maintaining, or declining performance. There are two levels of measures within operations functions: top-level key performance indicators that indicate if a process is starting to get out of control; and diagnostic measures used for problem solving, process improvement, and data analysis.

.1 Balanced scorecard

The balanced scorecard theory drives action from strategy by developing specific areas of focus and feedback. Operations controls the flow of inputs and outputs of an organization and is involved in the scorecard through its impact on financial, customer, and internal business processes. Specific aspects of the balanced scorecard theory include the following.

Revenue growth and mix. Operations management has a major impact on the growth of the firm through capacity considerations and new product and service introduction.

Cost reduction and productivity. Operations often owns the biggest share of cost reduction in the business. Cost of sales—made up of material, labor, and overhead—typically represents a large component of costs in the organization.

Asset utilization and investment strategy. Operations typically controls the major capital investments in the organization, including plants, equipment, and inventory.

.2 Benchmarking

Benchmarking is the act of comparing one operation or process with another. This can be performed against similar operations but can be especially effective if done against best-in-class operations, regardless of the market. For example, benchmarking quality at a tool manufacturer against aerospace standards, or benchmarking product introduction against the electronics market.

.3 Best practices

Best practices are techniques, methods, processes, activities, or other actions in conducting business that are most effective at delivering a particular outcome. By seeking out relevant best practices and driving improvements against these examples, gains typically can be made more quickly.

2.2 Supply chain strategy

Supply chain strategy considers the following, as well as all the elements of operations strategy listed previously.

2.2.1 Building strategic partnerships

One effective way to reduce costs and improve service in the supply chain is to develop strategic partnerships. These alliances should be chosen based on the overall strategy of the firm, and are typically limited to suppliers of strategically important goods and services. These partnerships are based on trust and rely on predictable communication streams and management systems. Rules of engagement between the parties normally include how schedules are communicated, how engineering changes are executed seamlessly, how engineering expertise is shared, how often deliveries are expected, how often demand expectations are forwarded or otherwise made available to the supply chain, and how suppliers are involved with product and processes at the customer's site.

Other considerations in these partnerships include what securities are offered in terms of longer contract expectations, defining options and features and their lead time expectations, and any other communication requirements specified by either party.

2.2.2 Insource/outsource (make-buy)

Outsourcing decisions generally are made to improve service or cost for the supply chain. An outside firm is selected to provide a good or service that currently is provided internally. Outsourcing normally occurs when off-site resources are better suited for a particular task; however, these tasks typically are not core competencies of the firm.

Some important factors to consider when deciding whether to insource or outsource: costs of production; costs of transportation; costs of ordering, which can range from a simple pull signal to bulk orders in more complex systems; costs of delivery time, such as transportation time for a part or service agent; quality assurance of the potential supplier; and the loss of proprietary processes or other trade secrets.

Also influential are any flexibility benefits the supplier can offer, especially where the supplier might be able to trade capacity or products between multiple customers, such as a freight forwarder using truck space to ship product from more than one customer, and any other competitive considerations, such as the supplier's relationship with the firm's competitors.

One of the most frequent areas of outsourcing in recent years is in the use of third-party logistics (3PL) providers. This usually means subcontracting traffic operations, but sometimes more comprehensive services are provided. This choice is based on the same cost-benefit analysis as any other sourcing decision. In many such decisions, economies of scale are brought to bear in the 3PL's ability to negotiate with freight companies. Unique skill and knowledge requirements drive many global shipping and receiving transactions; subcontracting these duties is often attractive due to cost considerations.

2.2.3 Drivers of supply chain performance

The drivers for performance of the supply chain are no different than those for the end member of the supply chain, or the customer. These drivers include quality, speed, delivery fidelity, flexibility, pre- and post-service, and cost, as well as the following factors.

Facilities. Supply chain performance often is affected by the design and location of facilities. Having facilities in close proximity enables flexibility as well as ease of communication. Network optimization studies can be performed to design a network of manufacturing sites, service areas, and distribution centers to deliver the lowest cost with optimal inventory and capacity levels.

Inventory. Inventory can improve supply chain flexibility by acting as a buffer to decouple supply from demand when appropriate.

Transportation. Transportation decisions can make major differences in both benefits and costs. Air freight is fast, but it is also expensive. Ocean freight can be economical but add weeks to the cumulative lead time. Speed and flexibility are factors in a total cost analysis, given the global competition in markets.

Information. Another major influence on supply chain effectiveness is the ease at which information is shared up and down the chain. Collaborative planning efforts are where suppliers and customers make joint decisions regarding costs and service risks. Information elements can include demand, new product plans, product design changes, and consolidation of freight into milk runs.

Sourcing. Sourcing decisions are important within the supply chain and rely on the maintenance of standards and policies. Changes to products several levels down the chain can manifest as problems at the end-user level. Changes to critical products and components need to be communicated and even approved by other parties further down the chain.

Pricing. Pricing is perhaps the most important strategic decision. Whether price is set high, low, or in the middle sends a strong message to all members of the supply

chain, including competitors, customers, suppliers, and potential new entrants. Price must be set in concert with the firm's overarching strategy of being a differentiator, a cost and price leader, or a niche player.

2.2.4 Synchronization

Synchronization is the simultaneity and speed of movement of information, funds, and goods or services through the supply network. Scheduling the supply chain effectively requires a clear demand signal to reach the extremities of the chain. Knowing when products are needed, where the inventory buffers will be held in the supply chain, and what the flexibility requirements and rules of engagement are greatly increases the overall performance of the supply chain. This flow and pace is enhanced by the free sharing of information and data.

2.2.5 Integration of suppliers, internal supply chains, and customer systems

The integration of supply chain elements is the essence of an effective supply network. Collaborative planning and sharing of information and data is critical to synchronized, efficient flow of material to the end user of the supply chain. Some concepts and commonly used acronyms in supply chain integration include the following.

Supplier relationship management (SRM). SRM is the focus on collaborative planning goals and processes between customers and their suppliers.

Internet supply chain management. With the introduction of the internet into everyday commerce comes the need for structured coordination of this commerce. Complex networks have developed that require free-flowing data streams. A major online bookstore is an example where many book suppliers are networked to create a virtual bookstore with almost unlimited resources. Stock balances and availability are widely visible through the network.

Customer relationship management (CRM). CRM is about understanding the customer and making sure that process design appropriately supports the customer and that communication streams are frequent and flow freely. Handshake management is often used in the description of CRM and refers to well-understood, well-defined expectations and accountability for those expectations. Communication is extremely important in developing an improved understanding of the customer.

2.2.6 Breadth of activities (designing, planning, controlling)

The activities within supply chain management are diverse and numerous for designing, planning, and controlling. In many respects, these activities correspond with the activities of a single business, but on a scale that incorporates the needs and capabilities of several businesses within a supply network with the goal of enabling the entire supply network to function as a single, virtual entity.

2.2.7 Reverse logistics

In many supply chains, the need to take inventory back to the source may arise. Examples include companies that process warranties and remanufacturers requiring cores returned for reconditioning. Often, inbound freight can be coordinated with outbound

freight, lowering transportation costs. Other times, considerations such as consolidation at collection points are taken. Sustainability needs are playing an ever-increasing role in driving the growth of reverse logistics as firms are driven, sometimes by legislation, to collect and properly recycle goods they have sold. (See section 2.3.8.)

2.2.8 Product sustainability

Product sustainability is the ability to produce and distribute product over time without exhausting nonrenewable resources and in a manner that minimizes the impact on the environment.

2.2.9 Regulatory compliance

All businesses must be aware of governmental regulations and required compliance. Examples of regulations in the United States include the Sarbanes-Oxley Act regarding ethical practices and generally accepted accounting practices (GAAP) regarding financial reporting. As trade opens across the world, more and more countries add regulations, making regulatory compliance of global companies more complex.

2.2.10 Global considerations

As trade is opened to global sources and customers, many global considerations are needed to cover the wide array of possibilities in customer requirements.

2.3 Sustainability

In operations and supply chain management, sustainability is the idea that business can help ensure that markets, commerce, technology, and finance advance in ways that benefit economies, societies, ecosystems, and stakeholders in general—or, at a minimum, do no harm—and contribute to a more maintainable and inclusive global economy.

2.3.1 Triple bottom line (TBL)

The TBL refers to people, planet, and profit. In TBL reporting, environmental, social, and economical aspects all are equally considered.

.1 Life cycle assessment

Life cycle assessment is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service by compiling an inventory of relevant energy and material inputs and environmental releases evaluating the potential environmental impacts associated with identified inputs and releases interpreting the results to make a more informed decision.

.2 Corporate social responsibility

Corporate social responsibility means using fair and beneficial business practices regarding labor and the community or region where a firm conducts its business. It is about providing a safe work environment, giving back to a community by contributing to health care and education, and avoiding the exploitation of labor and resources of an area.

.3 Economic prosperity

Economic prosperity refers to supporting those that provide financial capital in the form of earnings and related benefits, and boosting the economy of the society.

2.3.2 Sustainable supply chain

Sustainable supply chains seek clean methods of production, minimization of the environmental footprint of products and services, and combining environmentally friendly decisions with effective supply chain practices. Clean production focuses on

- waste minimization and avoidance
- reusing waste products when possible
- reclaiming products at the end of useful life
- preventing or reducing pollution at the source
- substituting for toxic and hazardous materials
- reducing waste and potential pollutants in product or service as well as transportation to market.

.1 Drivers of sustainable supply chains

Brand image. Creating competitive advantage for the firm, including attracting customers, employees, and partners who also value sustainability.

Innovation. Introducing new products that are environmentally friendly and providing a new source of revenue.

Cost cutting. Recycling products or making changes to processes that reduce costs and are more efficient.

Environmental awareness. Addressing problems such as global warming, toxic substance use, and use of non-replenishable resources.

Regulations. Complying with environmental regulations and standards such as the Clean Air Act, the Occupational and Safety Health Act, and the Pollution Prevention Act in the United States; the Restriction of Hazardous Substances Directive in Europe; China's Air Pollution Control Law; and ISO 14000.

.2 Closed-loop manufacturing

Closed-loop manufacturing is a system in which a product is created using renewable energy, with no pollutant output and no waste—the materials used in production are recycled and reused, not discarded. Products are built for durability and reuse, and producers are responsible for the entire product lifecycle, including the post-consumer phase. The concept is rooted in circular concepts of product design and production.

2.3.3 Sustainable new product development

Design for the environment, or eco-design, integrates environmental considerations into product and process design. Developers use tools and practices that encourage

environmental responsibility while reducing costs, promoting competitiveness, and enhancing innovation, but also maintaining price, performance, and quality standards.

Eco-design encourages designing products with more renewable supplies and less materials (for example, dematerialization), sharing resources (for example, car clubs and rental services), integrating product functions (for example, a combination scanner, printer, copier, and fax machine), and optimizing functions (for example, reducing packaging through better design).

2.3.4 Green six sigma

Green six sigma is taking standard lean and six sigma philosophies and applying them to the improvement of environmental sustainability.

2.3.5 Sustainable procurement

This refers to procuring goods and services with less impact on the environment than other products or services meeting similar performance requirements. Key elements include buying energy-efficient or recycled products incorporating packaging that is reusable, recyclable, or compostable and eliminating packaging where possible working to eliminate toxins and pollutants from cleaning solvents encompassing green ideals when building and maintaining facilities.

2.3.6 Total cost of ownership

From a sustainability standpoint, total cost of ownership is consideration of the entire cost of the product as part of sourcing, from purchase to final disposal. This includes

- **Acquisition costs**—Costs related to raw materials, purchase planning, quality, taxes, purchase price, and financing
- **Ownership costs**—Costs related to energy use, maintenance and repair, financing, and supply chain/supply network
- **Post-ownership costs**—Costs related to disposal, environment, warranty, product liability, and customer service/customer dissatisfaction.

2.3.7 Carbon footprint analysis

A carbon footprint analysis is performed to measure the amount of carbon dioxide and other greenhouse gases released during the making, shipping, storage, and use by consumers of goods and services. Often, it is found that use by consumers is a greater factor than production in determining how much of these gases are released.

2.3.8 Reverse logistics

Reverse logistics is planning, implementing, and controlling the flow of materials, finished goods, and related information from the consumer to the producer for the purposes of recapturing value or proper disposal.

2.3.9 The sustainable roadmap

This refers to establishing a vision, or roadmap, of sustainable principles for a business. The process includes steps such as

- placing sustainability and social responsibility at the core of professional practices
- educating stakeholders on sustainability concepts, including all employees and partners throughout the supply chain
- developing and improving practices, processes, products, services, and standards that lead to a sustainable supply chain
- incorporating the waste principles of reduce, reuse, and recycle to all resources
- measuring performance and setting targets for improvements.

2.3.10 United Nations Global Compact

The UN Global Compact is a set of strategies for businesses to help them align goals and policies with universal principles surrounding human rights, labor, environment, and anticorruption. The 10 principles of the UN Global Compact are reproduced below.

- **Human rights**

  1. Businesses should support and respect the protection of internationally proclaimed human rights; and make sure that they are not complicit in human rights abuses.

- **Labour**

  1. Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining;
  2. the elimination of all forms of forced and compulsory labour;
  3. the effective abolition of child labour; and the elimination of discrimination in respect of employment and occupation.

- **Environment**

  1. Businesses should support a precautionary approach to environmental challenges;
  2. undertake initiatives to promote greater environmental responsibility; and encourage the development and diffusion of environmentally friendly technologies.

- **Anti-corruption**

  1. Businesses should work against corruption in all its forms, including extortion and bribery.

2.4 Operations management links to other functional areas

2.4.1 Corporate strategy and the business plan

The business plan arguably is the most important document and directional tool for a business. The business plan usually is made up of the following three layers.

The strategic plan. This plan typically looks three to five years into the future. It normally is reviewed annually, and sometimes quarterly, depending on market conditions. The plan, from an operations view, is to project plant and equipment needs and corresponding funding requirements.

The annual operating plan (AOP). The AOP is the financial direction for the company and typically projects 12 months into the future. This normally is the link to the top management sales and operations planning process. Lists of assumptions usually are documented and support the logic of the AOP. It typically is fixed or locked for measurement purposes, but often undergoes quarterly updates.

Business imperatives. This list of objectives takes the strategic plan and the AOP and outlines specific goals and priorities to ensure they are executed as planned, if possible.

2.4.2 Operations and enterprise economics

Enterprise economics refers to the financial influences on spending and investment in new product development and capital spending and improvement in enterprise operation. From a supply chain perspective, these same influences can impact the functionality of product flow and data streams.

.1 Value creation

Value creation is taking raw materials or knowledge and converting it into a product or service that has more value to the customer than the original material or data. Value is created using transformational processes. (See section 2.1.1.)

.2 Financial accounting

Profit is the most significant measure of business success. Financial accounting is the scorekeeping process of determining the success or failure rate of a business. With information collected in real time in many cases, data typically is compiled and summaries distributed on a monthly basis, though some organizations do this more frequently. Following are some terms and considerations involved in financial accounting.

Income/expense. Income is revenue less expenses. Revenue is the gross currency value coming in from the sales of goods and services and expenses are all the costs of doing business.

Cost of goods sold. Cost of goods sold, otherwise known as cost of sales, consists of three elements: direct labor, direct material, and overhead. Overhead refers to indirect expenses from support materials and activities, such as process engineering, materials management, and production-wearable items.

Gross margin. Gross margin is the balance after cost of goods sold is subtracted from revenue.

Balance sheet. The balance sheet is a statement of financial position, based on the accounting equation of assets being equal to liabilities plus owners' equity.

Return on assets. Return on assets is a financial measure comparing wealth created from a project or investment to the assets required to make that wealth.

Inventory turns. The inventory turns calculation is one popular measurement of inventory management. It is a comparison calculation between existing inventory and the expected annual usage. It can be calculated on a specific stock-keeping unit }by volume, but is more frequently done at the aggregate inventory level calculated on the basis of value. Inventory normally is an asset on the balance sheet. Some companies use the inverse of inventory turns, resulting in an indication of the amount of time it would take for current inventory to run out, often expressed as days or weeks of supply or days inventory forward.

Capital asset management. Capital assets refers to large property such as land, machinery, buildings, and other equipment. Capital asset management is the planning and control of the use of these assets. This can lead to the sales of unused assets or marketing plans to increase demand for other assets, which would improve utilization.

Cash management. Cash is the lifeblood of an operation. It enables employees as well as raw material and service providers to be paid. Managing cash is making sure the amount of cash flow coming in is greater than or equal to the cash flow going out. This adjustment leverage can come anywhere from holding payment on accounts payable to delaying purchases. It can also be adjusted with revenue impact activities such as discounts for quick payment of invoices and discounting to generate quick sales or collection of accounts receivable.

.3 Break-even analysis

Break-even analysis is the comparison of revenues and expenses of both fixed and variable costs in order to identify the point at which revenues cover all expenses. When comparing the costs associated with different production methods, as in manual versus automation, the volume where the cost is the same is referred to as the point of indifference. Break-even analysis finds the break-even point, which is the volume at which revenues exceed total costs.

.4 Best operating level (BOL)

BOL is the capacity for which a process was designed and thus the volume of output at which average unit cost is minimized. Full theoretical capacity often is not sustainable for long periods. The BOL can be a complex trade-off between the allocation of fixed

overhead costs and the cost of overtime, equipment wear, defect rates, and more. (See section 2.1.6.)

.5 Cost accounting

Cost accounting is the process of keeping track of all costs of building products, labor, material, overhead, and variances. Activity-based costing (ABC) is cost accounting using actual costs rather than standard costs with variances. ABC accounting requires touch points throughout the process to pick up actual costs as they happen.

Cost analysis and control is done within cost accounting to assure the best overall financial results. Consideration of how operations management decisions regarding the location and valuation of products and services affect financial interests such as taxes and tariffs helps ensure the best financial benefit for the firm. There is also sufficient decision-making freedom in accounting practices that the impact of purely financial decisions, such as the method for valuing inventory or depreciating capital, should be understood fully to ensure such decisions benefit the firm.

2.4.3 Marketing

Marketing's responsibility is to affect customer behavior and grow the business. There are two common ways to grow a business: attracting new customers, and convincing existing customers to buy more. Marketing is involved in both areas, affecting customer behavior through promotions, pricing, distribution channels, and product design, and they are strongly involved in new product and service innovation.

2.4.4 Human resources

Human resources is responsible for the human component of company assets. High-potential employees can create higher levels of value to the company through investments in human capital. This includes investments in skills, knowledge, and availability. Following are some concepts involved in human resources.

Team building. Team building is the act of getting groups of people working together in sync by building on the interaction of different skills of team members, thus making the teams more effective within the company.

Training. Training is an important function of human resources, as people are provided with the instruction to perform job tasks. Training properly explains to people the transactions and processes they will use.

Education. Education is the "why" and the "what" of learning, where training is the "how to." In inventory accuracy classes, for example, education would describe why it is worth the effort to maintain accurate inventory balances, while training only explains how to perform the transactions.

Development. The goal of investments in human capital is employee development. Investments in education and training result in employees who are more prepared to solve problems, lead projects and people, and generally bring value to the company. Development prepares employees for their next positions and is critical to succession planning for the firm's sustainability and for long-term employee loyalty.

Empowerment. Empowerment relates to workers having authority, such as to stop a production line if there is a quality problem or to give a customer an on-the-spot refund if service was not satisfactory. Through empowerment, employees become involved and take ownership of their processes.

Rewards. Rewards refer to mechanisms designed to motivate workers to work efficiently. Approaches include piece rate and group incentive programs, and mechanisms for public recognition of outstanding performance.

2.4.5 Organizational development and managing change

Organizational development means carrying out a strategy to build high levels of effectiveness of an organization through proper accountability, improved levels of skill and knowledge, and strong communication of corporate objectives. Agents of change aid in overcoming resistance to new methods and assisting in implementation to facilitate organizational growth.

Dimensions of change. As markets, technology, cultures, and customer expectations change, so does business. Change happens on many levels and includes employee expectations, management roles, technology improvements, and customer expectations. Change happens earlier in the cycle when leaders recognize the need faster.

Drivers and obstacles. Drivers are forces that lead people to change, such as a financial crisis, a champion or trailblazer leading others, technology that shifts a market toward different designs in products, and laws such as ecology-supporting legislation. Obstacles to change are always present. They include cultural norms, lack of training, lack of leadership, and more physical obstacles such as lack of resources.

Overcoming resistance. Overcoming resistance is a function of communication and education. If a good idea is not accepted, it generally is because people do not consider it a good idea. Employee involvement should begin early in the planning of the new state to aid in overcoming resistance.

Human behavior and motivation. Humans are interested in identifying their personal gain or loss as it pertains to requested or required actions. The level, direction, and persistence of effort people are willing to expend is related to the expected rewards and punishments for their actions. The importance placed on a personal consequence is based on the individual's needs and can range from money for food to personal growth and development. Therefore, people are more likely to be motivated to solve problems when they are rewarded for trying; these rewards are not necessarily financial. Recognition, personal growth, and satisfaction can be the best motivators.

2.5 Product and service design

Product and service design refers to the entire process of engineering a potential future product or service, including its form, fit, and function.

2.5.1 Life cycle planning

Life cycle planning is the concept and practice in firms providing goods and services to plan strategically for the phases of a product's or service's life. After several research and development-related stages, including product conceptualization and technical demonstration, operations is concerned with these stages: introduction, growth, maturity, and decline.

Introduction is the initial launch of the new good or service. Growth is the increase in customer base as the item gains acceptance and typically is where the break-even point is reached. Maturity is the stabilization of volume and increased competition, often resulting in the need for lowering costs and price. Decline is the drop and eventual end of sales as the good or service is no longer in demand. Each stage requires a strategic alignment of the firm's resources to support the marketing and delivery of the product or service.

2.5.2 Design for manufacturing/assembly

Sometimes referred to as design for manufacturability, this is the practice of designing products—including the setting of tolerances and the specification of materials—in such a manner to streamline the processes and equipment required. The goal typically is to create a product design that meets all of the customer's requirements and is the least costly to manufacture.

Component commonality. This is the practice of using the same components in various end items to simplify the design process, contain costs, simplify the procurement of common components, and reduce variability in the storage of the components and the manufacture of the end item.

Modularity and robustness. Modularity is related to component commonality in that a standard or common module is used to complete a variety of end items with the goals of cost containment and simplification. Modularity can increase flexibility with respect to the firm's ability to offer customized end items. Conversely, the use of modular construction can have a limiting effect on the total range of customization that can be offered. Robustness is the ability of a design or service to withstand external detrimental forces and still deliver the desired functionality, or to deviate from the desired functionality only minimally. For example, many products are designed to accept minor variations in electrical current; however, computers and other sensitive equipment often require a surge protector.

Global standardization. These are practices by firms who have a global strategy to standardize products, components, practices, and service offerings. Such standardization takes the form of designing and altering products, parts, processes, and procedures to establish and use standard specifications and reduce the total numbers of parts and materials used and products, models, or grades produced.

2.5.3 Concurrent engineering

This is the practice of simultaneously involving all relevant fields and departments like marketing, research and development, product and process design, manufacturing, distribution, and field service in the entirety of new product design and introduction

with the goal of reducing time to market. This often is accomplished by cross-functional teams made up of individuals representing the different functions that are involved throughout the entire design process and may extend beyond organizational boundaries to include supply chain partners in the design phase. The opposite practice is sequential engineering.

2.5.4 Computer-aided design (CAD)/computer-aided manufacturing (CAM)

CAD and CAM are technologies used by designers and manufacturing engineers. CAD is used for product design and CAM is used for manufacturing process design. Both are computer drawing boards able to calculate strengths and capacity factors, predict stress points, predict mean time between failures, and offer other faster functions that previously required significant time.

2.5.5 Basic process types

The processes used for producing a good or service need to match the volume and flexibility needed. Basic process types include job shops or work centers, work cells, assembly lines, and continuous flow processes.

2.5.6 Group technology

This is the process of categorizing design shapes and processes to streamline the production and design process. Group technology is an important part of data organization and is used as a background management system within CAD. It also can provide a basis for the design of manufacturing cells.

2.5.7 Quality function deployment (QFD)

QFD is a methodology that shows relationships and dependencies on quality areas, product capabilities, and product qualities as understood from the voice of the customer. The complexity of achieving each specific characteristic is also considered. The house of quality (HOQ) is normally used for the management of QFD.

The HOQ is a multistage, structured process that relates customer-defined attributes to the product's technical features, to the necessary parts and components, to the processes used to build those parts and components, and ultimately to a control process that monitors and assures the process is performing to specification.

2.5.8 Sustainability

See section 2.3.

2.5.9 Design for logistics

See section 3.6.

2.5.10 Reverse logistics

See section 2.3.8.

2.6 Strategic capacity

2.6.1 Learning curve

This is a phenomenon where the labor content of large manufacturing projects, such as aircraft, decline steadily as cumulative production increases. This decline in labor content is predictable and related to a doubling of production. The curve takes the form of an exponential decay curve.

When planning for changes in capacity, it is prudent to plan for ramp-ups or ramp-downs. There are stress points in all organizations at which adjustments to certain levels of magnitude are not immediate and automatic. For example, when adding a new product line, it would be normal for at least a short interval of less-than-peak capacity as workers get used to the new product and pace. This would be equally true of service organizations as they get used to new services. Learning curves are variable and can be minimized through investments in training, education, testing, and practice prior to full implementation.

2.6.2 Timing and sizing considerations

See section 2.1.7.

2.7 Project management strategic uses

Project management is the management system that enables business imperatives and strategic goals to be accomplished. If growth is a goal, for example, projects are developed to introduce new factors affecting customer behavior. Project management is the methodology by which goals are assigned and resources and plans are developed and monitored to achieve these goals. See Chapter 7 for additional information.

CHAPTER 3

Supply Chain

Current ideology behind the supply chain is to apply a total systems approach to designing and managing the entire flow of information, materials, and services from raw materials suppliers, through factories and warehouses, and finally to the customer. The term "supply chain" comes from the visual representation of how organizations are linked together as viewed from a particular company. The chain has many links, such as those between suppliers that provide inputs, links to manufacturing and service support operations that transform the inputs into products and services, and the distribution and service providers that localize the product.

3.1 Responsiveness, agility, and efficiency

Responsiveness is the ability of the supply chain to meet the changing and diverse needs of customers. Agility refers to the ability of a firm to manufacture and deliver a broad range of high-quality products and services with short lead times and varying volumes to provide enhanced value to customers. Efficiency refers to the ability to do this at low cost.

Typically, there is a trade-off between such factors as cost and speed of delivery. For example, a firm's ability to efficiently deliver a broad range of products at low cost depends on the relative certainty of supply and demand. The stable supply base and relatively predictable demand associated with commodities enables an efficient supply chain. At the other extreme, firms that produce innovative products with short life cycles using the latest technologies need a more agile supply chain.

3.2 Supply chain visibility, synchronization, and bullwhip minimization

In the simplest terms, supply chain management is balancing or synchronizing supply with demand. Lead time considerations and demand variability can make this a difficult task. The bullwhip effect is the phenomenon of variability magnification as the view moves from the customer to the producer in the supply chain. The effect indicates a lack of synchronization among supply chain members where, for example, a small change in consumer sales ripples backward in the form of magnified oscillations upstream, resembling the result of a flick of a bullwhip handle. Because the supply patterns do not match the demand patterns, inventory accumulates at various stages, and shortages and delays occur at others. Collaboration and communication between supply chain members is one way to minimize the impact. Information visibility in inventory levels, anticipated production, and material in transit is needed by supply chain members to successfully coordinate the supply chain.

3.3 Risk management

This section covers the management of risks surrounding unanticipated events that disrupt the normal flow of goods and materials within the supply chain. These

uncertainties can be categorized across two dimensions: coordination risks, or those associated with the day-to-day management of the supply chain, which are normally addressed using principles such as safety stock, safety lead time, and overtime; and disruption risks, which are caused by natural or man-made disasters such as earthquakes, hurricanes, and terrorism.

Primary focus in this section is given to the concepts and tools that manage disruption risks. Events related to disruption risks contain a great deal of randomness and are virtually impossible to predict with any precision.

3.3.1 Risk management framework

Disruptive supply chain risks lend themselves to a three-step risk management process, which consists of the following steps.

Identify the sources of potential disruptions. The first step is to assess the types of vulnerability in a supply chain. The focus should be on highly unlikely events that would cause a significant disruption to normal operations, including natural disasters, capacity failures, infrastructure failures, terrorist attacks, supplier failures, labor actions, equipment failures, price volatility, and military and civil conflicts.

Assess the potential impact of the risk. Next, quantify the probability and the potential impact of the risk. The assessment depends on the specific incident, but it can be based on factors such as finance, environment, business viability, brand image and reputation, and human lives.

Develop plans to mitigate the risk. Finally, create a detailed strategy for minimizing the impact of the risk. These strategies can take different forms depending on the nature of the problem.

The following table contains some examples of risk mitigation strategies.

Risk	Risk mitigation strategy
Transportation failure	Use of redundant vehicles, modes, and operators
Supplier failure	Sourcing from multiple suppliers
Climate change, inclement weather	Contingency planning, including alternate sites; insurance
Licensing and regulation issues	Up-front and continuing research; legal advice; compliance
Major quality failure	Careful supplier selection and supplier monitoring
Loss of customers	Innovation of products and services
Theft/vandalism	Insurance; security precautions; knowledge of likely risks; patent protection

3.3.2 Risk mapping

Risk mapping involves assessing the probability or relative frequency of an event against the aggregate severity of the loss. Some risks might be deemed acceptable and

part of the normal costs of doing business. In some cases, firms may find it possible to insure against the loss. In other cases, the potential loss is great enough that the risk needs to be avoided altogether.

3.4 Locating facilities

See section 3.7.2 for a description of quantitative techniques related to locating facilities.

3.5 Distribution

Distribution centers around the activities associated with the movement of material, usually finished goods or service parts, from the manufacturer or distributor downstream to the customer. These activities include transportation, warehousing, inventory control, material handling, order administration, site and location analysis, packaging, information systems, and communications networks.

3.5.1 Modes of transportation

Choosing a method of shipment is a critical decision for distributing products. The basic modes of transportation are highway, rail, water, pipeline, and air. Each method has its own trade-off between costs and benefits that must be considered, such as freight charge versus time to move.

3.5.2 Channels of distribution

Channels of distribution are any series of groups or individuals that participate in the flow of goods and services, from the raw material suppliers and producers to the final users or consumers. The terminology is used to reflect the intermediate companies and steps in the distribution process. For example, items can be sold directly from the manufacturer to the consumer, or they can be sold though a wholesaler, distributor, or retailer to reach the end user.

3.5.3 Cross-docking, break-bulk, and unitization packaging

Cross-docking. Cross-docking is a distribution technique in which items are brought into a distribution center for immediate dispatch. Instead of being received and stored away, these items are loaded into the distribution center's sorting system or are taken directly to shipping for sorting and dispatch. This may require the vendor to perform some additional value-added step, such as hanging garments on hangers, repackaging the item for easier sorting, or adding labels such as a price tag to the item.

Break-bulk. Break-bulk handling is dividing truckloads of homogeneous items into smaller, more appropriate quantities for use. In trucking, this consists of loading many shipments into a truck destined for a specific location. The freight is then "broken" to other trucks headed to additional destinations until it arrives at the local destination where it is "broken" to a local delivery truck.

Unitization packaging. Unitization packaging is the consolidation of several units into larger units for fewer handlings, such as placing items in boxes loaded and wrapped as a pallet. In terms of distribution, unitization will cost more because of the additional packaging, but this cost can be offset by the savings from shipping one

large unit versus many smaller units.

3.6 Warehousing

Warehousing activities relate to receiving, storing, and shipping materials to and from production and distribution locations.

3.6.1 Warehouse layout

Warehouses often are configured to have formal storage locations that identify the row, rack section, level, and shelf location, typically with an alphanumeric location bar code or label. For example, the location label B3A4 would identify Row B, pallet section 3, shelf A, and shelf location 4.

Fixed versus random storage locations. This refers to whether items are permanently assigned to a location or the assignments are made dynamically as space is freed. Often some combination of both methods is used.

Fixed locations. Fixed locations are appropriate for high-volume picking. Fixing locations, along with logical location slotting—placing high-turn items closest to packing and shipping areas—enables a warehouse to be configured to reduce picking and put away times, saving transportation within the warehouse.

Random locations. Random locations are appropriate where travel distances are not an important consideration and when overall utilization of warehouse space is important. Random locations are often used for high-variety storage. Computers often manage this process.

3.6.2 Material movement

Material movement inside a warehouse is governed primarily by the type of product being stored. Cube size and weight are factors, as are storage and shipping configurations. Examples of equipment used for material movement include:

- **forklifts** to move and lift pallets of materials into and out of storage units.
- **pallet jacks** to move pallets of materials short distances for loading and unloading trucks and case picking onto pallets.
- **pick carts** to handpick single items and small case picks.
- **conveyors** to move cases or single items from place to place within a warehouse from pick locations to a packing area. Items can be placed into totes or boxes to facilitate movement on the conveyor. The conveyor can also be used to put case stock away.
- **automatic material handling systems,** which apply technology in the form of warehouse management systems and bar code scanners to conveyor systems in order to move and sort items within a warehouse. When picking is complete, the system directs items to the correct packing station or loading dock.

3.7 Logistics

In an industrial context, logistics is the art and science of obtaining, producing, and distributing materials and products in the proper place and with the proper quantities. In a military context, logistics also includes the movement of personnel, as well as the design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of materiel.

3.7.1 Design options

The design process consists of translating a set of functional requirements into an operational product, process, or service. Options to consider include the design of the distribution network, the product itself, and the production or distribution facility, as well as the related concepts of design for manufacture and assembly and design for the environment. Several of these design options can affect the logistics of the system, including product size, package configuration, product variety, and product perishability.

Direct shipment network. In a direct shipment network, suppliers establish a system of shipping directly from the supplier to the customer without any intermediate parties in the distribution system.

Direct shipment with milk runs. A milk run is a regular route to pick up mixed loads from several suppliers. A combined or consolidated delivery from multiple suppliers often is a part of milk runs. For example, instead of five different suppliers sending a separate truckload each week to meet the weekly needs of the customer, one truck visits each of the suppliers daily before delivering to the customer's plant. Direct shipment using a milk run consolidates multiple vendors' deliveries into one direct shipment to the customer, enabling the customer to process one full truckload instead of multiple less-than-full shipments.

Shipment via central distribution center. A central distribution center consolidates shipments to promote efficiency and provide strong customer service. The central distribution center may carry a set level of safety stock for the items it stocks. When the distribution center carries stock, it consolidates shipments of multiple commodities from multiple vendors to support the customer.

Cross-docking. In order to reduce inventory levels, safety stock requirements, and distribution cycle times, a central distribution center may employ cross-docking. Cross-docking is a system for packing products on incoming shipments to ease sorting at intermediate warehouses or on outgoing shipments, based on their final destinations. The items are carried from the incoming vehicle docking point to the outgoing vehicle docking point without being stored in inventory at the warehouse or distribution center. Cross-docking is a preplanned activity used to reduce inventory levels while improving customer response time.

Tailored network. A tailored network is part of the larger distribution network. The tailored network is designed in conjunction with the needs of the customer to provide the right quantity of products, in the right condition, to the right location and at a time dictated by the customer. A tailored network often involves some variation of any of the above models.

3.7.2 Qualitative techniques

Qualitative techniques are used when quantifiable data are not available or when measurements for different criteria relevant to the logistics decisions are used. A typical question with multiple criteria would be the ideal location of a plant or a warehouse. A common approach is evaluating each criterion based on a common point scale and combining criteria using weighted factors that indicate the importance of each criterion.

3.7.3 Quantitative techniques

Quantitative techniques enable the direct consideration of cost in evaluating logistics system designs. Trade-offs often involve costs related to transportation, inventory investment, and acquiring and managing facilities. Quantitative techniques are useful in solving such logistic problems as designing routes and scheduling vehicles.

Transportation models. A transportation model finds the optimal allocation of sources of supply—typically plants—to meet the demand at destinations in the network—typically warehouses. For each combination of source and destination, a per-unit cost (or profit) can be determined. Solutions are evaluated by taking the sum-product of volume multiplied by the cost or profit.

Network optimization. A logistics network is the interconnection of the facilities, transportation assets, and nodes that enable the efficient distribution of products between suppliers, manufacturing facilities, distribution centers, warehouses, and customers. Optimization is the process of achieving the best possible solution to a problem in terms of a specified objective. Optimizing the logistics network is the process of achieving the most efficient network to move materials and products from the supplier through the manufacturing process to the end user.

Vehicle routing. Vehicle routing is a subset of the logistics network optimization process. The goal of the routing process is to reach optimal efficiency of all vehicle assets within the network. Vehicle routing uses computer models that contain all customer and supplier nodes within the network and output routes and assignments that minimize the total distance traveled. The routing model may produce vehicle scheduling to optimize vehicle use and provide service continuity to customers.

3.7.4 Shipment planning

The goal of shipment planning is to maximize freight loads while minimizing freight costs. Shipment planning integrates movement demands with vehicle resources.

Load planning. Load planning is the process of determining what should be in a load and how the load should be organized to maximize weight and minimize volume. Load planning also includes the concepts of building mixed-commodity pallets for shipment and load sequencing based on multiple delivery stops.

Transportation planning. Transportation planning is used to coordinate the transportation assets of the company with the demand for shipments or with third-party logistics providers.

Route planning. Route planning is necessary to ensure efficient use of

transportation resources while meeting the needs of the customer. Routes must be coordinated with customers when the shipper guarantees a specific delivery time. The goal of route planning is to minimize transportation costs through load distance analysis while striking a balance between truck capacity and multiple stops created by less-than-full-load deliveries.

3.7.5 Capacity

In logistics and distribution, capacity of the network includes the carrying ability of the transportation choices. The number of trucks in the system—both available and required—and the ability of the distribution system to load these trucks and deliver on time to the customer are constraints on the system. Distribution networks must balance capacity and customer demands to remain efficient and effective.

3.8 International regulations

International regulations greatly impact decision making in the distribution system and include: customs regulations on what is restricted from entering a country; trade tariffs and duties on imported goods; security regulations, such as those contained in the SAFE Port Act; and trade agreements, such as NAFTA in the United States, or those of the European Union. International regulations may enhance or hinder the competitiveness of a country or protect a country's distribution and manufacturing systems.

3.8.1 Free trade zones (FTZs)

An FTZ is the international term for what is known in the United States as a foreign trade zone. An FTZ is an area considered outside of the host country's territory but supervised by its customs department. Material may be brought in to the FTZ without paying import duty taxes and assembled or manufactured into a finished product. Duties and taxes are then paid when the finished good is moved outside the FTZ for retail sale.

3.8.2 Tariffs, currencies, and trade blocs

Import and export taxes, relative currency valuation and volatility, and special agreements between cooperating countries often are significant considerations in the design and operation of a supply chain.

3.9 Strategic sourcing

Strategic sourcing is a comprehensive approach for locating and sourcing key material suppliers. This often includes the business process of analyzing the total cost associated with procuring an item or service. There is a focus on developing and maintaining long-term relationships with trading partners who can help the purchaser meet profitability and customer satisfaction goals. From an information technology applications perspective, strategic sourcing includes the automation of processes such as request for quote, request for proposal, electronic auctioning, business-to-business commerce, and contract management.

3.9.1 Purchasing cycle

The purchasing cycle is the length of time from when need for an item is determined to when the item is sourced, purchased, and delivered. The purchasing cycle consists of need identification, supplier selection (including development of standards for order qualifiers and order winners), price determination and negotiation, purchase order preparation, following up and checking on purchase status, acceptance and receipt of items, and payment of invoices.

Supplier selection. The process of selecting the best source for a commodity or service is a critical function of the purchasing or acquisitions department. For most common items, the purchasing office maintains a list of approved, qualified suppliers. For new items or for items without a qualified supplier, the purchasing office must conduct a decision analysis.

Part of maintaining a supplier database includes preparing reviews and supplier scorecards. Decision analysis models can be used to choose potential suppliers, as deciding on the right mix of suppliers and how orders will be allocated is an important aspect of supplier selection. Supplier selection may be limited to a sole source for some critical or proprietary components.

Processes and models. Multiple-criteria decision-making models are used when there is more than one criterion for critical decisions. These models may incorporate a number of factors, such as price, quality, delivery standards, and evaluations of past performance. A successful model may include a trade-off analysis between the established criteria. The analytical hierarchy procedure is a useful model when making supplier selection decisions.

3.9.2 Global partners

Global and extended supply chains create the need for international partners, especially in developing markets. A global partner may be a supplier of raw materials or components, an intermediary, a customs broker, or a retailing partner. Laws and regulations specific to a country may dictate how a global partner may enter the marketplace. Partnering usually is an indication of a long-term commitment based on mutual trust and a shared vision.

3.9.3 Supplier relationship management (SRM)

SRM is a comprehensive approach to managing how an enterprise interacts with the organizations that supply its goods and services. The goal of SRM is to streamline the processes between an enterprise and its suppliers. SRM often is associated with automating procure-to-pay business processes, evaluating supplier performance, exchanging information with suppliers, and supplier certification. E-procurement systems also are part of the SRM family of applications.

Third-party logistics (3PL) partnering. This occurs when a third party provides product delivery services and offers additional supply chain expertise. A 3PL company is an entity that manages all or part of another company's inbound and outbound

freight operations. This partnering between a manufacturer or supplier and a 3PL provider is a result of a trade-off analysis of cost and quality of service. It usually is the result of a review of the manufacturer or supplier's core competency and acknowledging that another company can provide the same or better service for less cost.

Supplier scorecard. Supplier scorecards are used to certify quality suppliers and negotiate prices on purchase orders. The purpose of a supplier scorecard is to evaluate the quality of the supplier's products, the timeliness of its deliveries and delivery cycle times, the number of returns or defective products, and customer complaints, among other variables. The supplier scorecard ties the company's short- and long-term goals to the supplier's performance and enables the company to rank suppliers, which may impact the allocation of orders. The scorecard is developed between the customer and the supplier with a mutually agreed-upon set of metrics.

Co-design and execution. Co-design and execution is the cooperation of customers and suppliers in the design of the distribution system in order to meet the needs of the customer, simplify delivery systems, and take advantage of throughput from the supplier to the customer. The process engages suppliers and customers in the design of the product or service, fully utilizing input and support from all facets of the supply chain.

Collaborative planning, forecasting, and replenishment (CPFR). CPFR is a process in which trading partners jointly plan key supply chain activities, from production and delivery of raw materials to producers and final products to end customers. CPFR encompasses the functions of business planning, sales forecasting, and operations required to replenish raw materials and finished goods. CPFR is an industry standard endorsed by the Voluntary Interindustry Commerce Solutions Association (VICS). (See section 5.11.)

3.9.4 Risk management

See section 3.3.

3.9.5 Sourcing

Sourcing is the process of selecting a company to provide a specific good or service. Sourcing often is associated with purchasing.

Single sourcing. Single sourcing is a method in which a purchased part is supplied by only one supplier. Traditional manufacturers usually use at least two suppliers for each component they purchase to ensure continuity of supply and to foster price competition between suppliers. A Just-In-Time manufacturer frequently has only one supplier for a specific part so that closer relationships can be established with a smaller number of suppliers. The disadvantage of single sourcing is the increased risk if the single source goes out of business or is unable to meet surges in demand.

Dual or multiple sourcing. These are methods of sourcing that use a few suppliers for the same products or services. The advantage of multiple sourcing is the flexibility and redundancy of support from multiple suppliers, coupled with the ability to use multiple sources to meet demand surges.

Sole source. The term sole source describes a situation where the supply of a product is available from only one organization. In these cases, barriers such as patents preclude other suppliers from offering the product.

3.10 Customer relationship management (CRM)

CRM is a marketing philosophy based on making the customer the highest priority. It consists of the collection and analysis of information designed for sales and marketing to understand and support existing and potential customer needs. This analysis includes account management, catalog and order entry, payment processing, and customer credits and adjustments.

Delivery and design. An effective design process links delivery and service with customer needs. The design process ensures that the customer's needs are met in a simple and cost-effective manner. The delivery process is not one size fits all; it must be designed and customized to meet customer needs and expectations while keeping the number of revisions low.

Contract and customer management. A successful CRM system includes a robust contract management protocol to ensure that contracts are sufficient to meet the needs of the company, with effective and efficient customer support always in mind. Although a company's primary purpose is to turn a profit, the company will not remain profitable in the long run without effective customer support that produces loyal customers.

Contract management. Contract management and administration are crucial to holding suppliers and customers accountable for meeting the work specified in a contract. Contract management includes developing specific statements of work or product specifications, finding sources of supply or service, negotiating with suppliers and vendors, evaluating contract performance against agreed-upon metrics, and evaluating product quality. Other functions of contract management include the evaluation of contract responsiveness, negotiating changes to a contract, and ensuring that the contractor is compensated for the products or services provided.

Customer management. Companies can affect the buying, purchasing, and contracting activities of the customer. The goal of customer management is to develop and maintain loyal customers, which usually is accomplished through customer loyalty programs that reward customers for repeat business. The company benefits by gathering information on customer buying habits and preferences, which the company uses to create targeted product offerings and promotions. Keeping customers satisfied and loyal is critical to company profitability and is one of the founding principles of customer management.

Companies use performance metrics taken from the customer's perspective, with criteria such as on-time delivery, perception of quality, percentage of complaints, and shortened customer wait times. These metrics are important in measuring customer satisfaction and developing loyal customers.

3.11 Lean management

Lean management refers to an approach to management that focuses on reducing or eliminating waste in all facets of the system.

3.11.1 Total cost of ownership (TCO)

TCO is the sum of all costs in every activity of the supply stream. Examining TCO brings the understanding that unit acquisition cost often is a small portion of the total cost of ownership. In a broader operations management sense, TCO refers to the total system cost of delivering a product or service to the customer.

3.11.2 Value stream mapping

The value stream consists of all the activities or processes necessary to deliver a product or service to the customer. Value stream mapping is a technique using flow charts to identify the key elements and activities in the process and flow of information. In value stream mapping, each activity is identified as either a value- or non-value-adding activity. Lean management seeks to minimize and eliminate non-value-adding activities from all processes.

3.11.3 Principles of lean management

Lean management is closely related to the concepts of the Toyota production system (TPS). It is applied not only in production but across the entire enterprise, and it has broad applications in the service industries. Lean management involves the systematic identification and elimination of waste throughout the entire value stream. In the TPS, waste is identified by the Japanese word muda.

The key points distinguishing lean from other management concepts is the broadening of the definition of waste to include time and inventory. Through this, lean production tends to evolve quickly into continuous flow, utilizing little or no work-in-process inventory, and ultimately reaching the goal of one-piece flow of the product or service.

There are seven categories of waste:

- **overproduction**—producing in excess or too early
- **waiting**—queuing delays around production areas
- **transportation**—unneeded movement of materials in and outside the facility
- **processing**—poor process design
- **movement**—staff activities that do not add value
- **inventory**—idle stock accumulating cost without necessarily providing value
- **defective units**—scrapping or reworking products and components.

3.11.4 Visual management

One lean technique to eliminate waste is thoroughly cleaning and simplifying the work environment to make activities instantly and visibly obvious. Visual management also enables ease of understanding the status and current performance levels of the work-

place. This is accomplished by making any issues visually stand out, such as missing tools, low inventory, and out-of-place products.

3.11.5 Five Ss

Sort, set in order, shine, standardize, and sustain are five terms beginning with the letter S used in creating a workplace suitable for lean production. Sort means to separate needed items from unneeded ones and remove the latter. Set in order (or simplify) means to neatly arrange items for use. Shine (or scrub) means cleaning up the work area. Standardize means to sort, simplify and scrub daily. Sustain means always following the first four Ss. These are sometimes referred to by the Japanese equivalents of seiri, seiton, seiso, seiketsu, and shitsuke.

3.11.6 Quick changeover (flexibility)

An early insight of lean was the realization that setup costs were a key element and constraint of eliminating waste in any value stream. Therefore, a key activity in any lean management system is to reduce or entirely eliminate the cost of changing from one product or service to another. Toyota's Shigeo Shingo developed a system known as single-minute exchange of die to systematically reduce the time for a setup to a single minute (or less than ten minutes). These techniques have broad applications throughout manufacturing and service industries. In the formula for economic order quantity (EOQ), as the cost of a setup approaches zero, EOQ approaches 1.

3.11.7 Kaizen (continuous improvement)

Kaizen is the Japanese term for improvement. Kaizen is continuing improvement involving everyone—both managers and workers. In manufacturing, kaizen is finding and eliminating waste in machinery, labor, and production methods.

3.11.8 Zero inventory (Just-in-Time)

In lean management systems, zero inventory is the ideal state sought in eliminating the waste (muda) of inventory. In an ideal lean system, a single piece of a product or service is moved through the value stream, completed, and delivered exactly at the time the end customer demands it.

3.11.9 Business process reengineering (BPR)

See section 4.4.5.

3.11.10 Supply chain performance metrics

Two common measures of supply chain efficiency are inventory turnover and week-of-supply. These are effectively measuring the same quantity: Mathematically, they are the inverse of one another. Other common measures include the percentage of orders shipped according to schedule, the percentage of actual line items filled from stock, and the time from when an order is placed to when it is received by the customer (lead time). More advanced metrics measure asset turnover and the time elapsed from cash spent purchasing materials into cash received from a customer.

CHAPTER 4

Processes

4.1 Process mapping

Process mapping is a visual form for documenting the details of a process. Depending on the process map's objective, the level of detail varies. Process maps can take many forms, including flowcharts; relationship maps; cross-functional maps; and supplier, input, process, output, customer (SIPOC) diagrams.

4.2 Manufacturing process environments

Manufacturers must design processes to conform to the nature and needs of their customer bases and the design characteristics of their products. For example, when the products created and the market served by the manufacturer are standardized commodities, the manufacturing processes and equipment are geared for high-volume, repetitive, lowest-cost production. On the other hand, when the market demands significant product differentiation, manufacturing processes are designed differently to provide flexibility.

4.2.1 Product/process matrix

Process selection refers to the strategic decision of choosing the method of production processes that will result in a product or service. General work flow patterns define the arrangements of facilities. There are five basic structures: project, job shop or work center, manufacturing cell, assembly line, and continuous process.

The relationships between layout structures often are depicted on a product-process matrix with two major dimensions. The first dimension is the volume of a product or group of standardized products produced. The second dimension is standardization, which refers to variations in the product. These variations are measured in terms of differences such as geometric, material, and others.

Facilities that match volume and product standardization characteristics generally are desirable. For example, if nonstandard products are produced at relatively low volumes, a project or work center layout is appropriate. A highly standardized product or commodity produced at high volumes would be produced using an assembly line or continuous process.

4.2.2 Make-to-stock (MTS)

In MTS environments, products are created before receipt of a customer order. Customer orders are then filled from existing stock, and then those stocks are replenished through production orders. MTS environments have the advantage of decoupling manufacturing processes from customer orders. Theoretically, this enables customer orders to be filled immediately from readily available stock. It also allows the manufacturer to organize production in ways that minimize costly changeovers and other disruptions.

However, there are risks associated with placing finished goods into inventory without having a firm customer order or an established need. These risks tend to limit MTS environments to simple, low-variety, or commodity products whose demand can be forecasted readily.

4.2.3 Assemble-to-order (ATO)

In ATO environments, products are assembled from components after the receipt of a customer order. The key components in the assembly or finishing process are planned and stocked in anticipation of a customer order. Receipt of an order initiates assembly of the customized product. This strategy is useful when a large number of end products based on the selection of options and accessories can be assembled from common components.

When products are too complex or customer demand is unpredictable, manufacturers may choose to hold subassemblies or products in a semifinished state. The final assembly operation is then held until a firm customer order is received. In this environment, manufacturers theoretically cannot deliver products to customers as quickly as MTS environments, since some additional time is required to complete the final assembly.

4.2.4 Make-to-order (MTO)

In MTO environments, products are made entirely after the receipt of a customer order. The final product usually is a combination of standardized and custom items to meet the customer's specific needs. MTO environments are more prevalent when customers are prepared to wait in order to get a product with unique features—usually customized or highly engineered products. This is analogous to the difference between a fast-food restaurant and a full-service chain restaurant. MTO environments are slower to fulfill demand than MTS and ATO environments, because time is required to make the products from scratch. There also is less risk involved with building a product when a firm customer order is in hand.

4.2.5 Engineer-to-order (ETO)

In ETO environments, customer specifications require unique engineering design, significant customization, or new purchased materials. Each customer order results in a unique set of part numbers, bills of material, and routings. ETO environments theoretically are the slowest to fulfill: Time is required not only to build the product, but to custom design it to meet the customer's unique requirements.

4.2.6 Process design

Manufacturers have many choices regarding the design and configuration of manufacturing processes to align with the demands of the market and product designs. Some elements of manufacturing processes are dictated by the product and the technology. For example, if heat-treating is required, the piece must be brought to a particular temperature and atmospheric environment, then cooled. This places constraints on the manufacturing process.

.1 Assembly line design

In this design, work processes are arranged according to the progression of steps in making the product. Discrete parts are made by moving from workstation to workstation at a controlled rate, following the sequence needed to build the product.

.2 Cell design

Cells are similar in nature to assembly lines, except that cells typically are smaller. They are also dedicated to a specific product, a group of similar products, or a specific customer. Cells are often configured in a "U" shape to facilitate communication among the workers in the cell. "L" and "S" shapes also are common. Cells typically are scheduled to produce as needed in response to current customer demand.

.3 Work centers (job shops)

Work centers, also known as job shops, are organized around similar processes rather than around product flow. For example, in the case of a machine shop, similar machines would be grouped together—lathes in one area, grinders in another, mills in yet another. Products move between groups of machines as required by their production requirements. As general-purpose equipment is used, work centers theoretically have the lowest investment costs in equipment.

.4 Hybrid systems

Many manufacturers use a combination of the previous process designs as dictated by the manufacturing environment, product design, and customer or market demands.

4.2.7 Focused factories

Focused factories are plants established to focus the entire manufacturing system on a limited set of products, technologies, volumes, and markets precisely defined by the company's competitive strategy, technology, and economics. A focused factory can achieve the lowest possible investment cost and have the best possible customer service due to the elimination of waste from market disruptions and changeovers. In a focused factory, the entire workforce, including management, is dedicated to satisfying the needs of its specific customer base or market niche.

4.2.8 Mass customization

In mass-customization environments, a process is created to support relatively high volume and variety. This has two advantages: Customers can choose specific product options and manufacturing costs can be kept low due to the volumes. An example of this system is found in personal computers, where a customer may specify processor speed, memory size, hard disk size, and many other options prior to the computer being assembled. Mass customization combines all of the cost advantages of mass production with the market advantages of high-variety, custom-made products. However, it is a difficult process to implement and requires close integration between product design, the manufacturing process, and the information system that captures the orders.

4.2.9 Capacity and flow analysis (bottlenecks)

A bottleneck occurs when one operation runs slower than others, such that its speed determines the output of the entire process. Capacity and flow analysis seeks to identify and manage the bottleneck operation. (See section 6.7.)

4.2.10 Time measurement and standards

Typically associated with industrial engineering, these are methods to scientifically study work and movement. These techniques are used to develop time standards for production activities and are used in the design of manufacturing processes to estimate manpower requirements and measure the productivity and output of the process.

4.3 Service processes

Services are defined in terms of interactions between the service provider and the customer. The level of service interactions ranges from face-to-face to written correspondence. Degrees of standardization can vary greatly among service processes. Some may be standardized to the point of automation, while others require considerable skill on the part of the provider to meet the customer's needs.

4.3.1 Classification of services

Services can be classified according to the level of customer contact with the technical core. The operating efficiency of a service is limited by the amount of customer contact. Production efficiency actually decreases with greater contact between the service provider and the customer, due to the higher level of customization.

High contact. In high-contact (or pure) service, a greater level of contact exists between service providers and customers. Examples include health centers, hotels, public transportation, retail establishments, and schools. This limits the amount of activities the service provider can perform and tends toward a greater degree of customization of the service delivered to individuals.

Medium contact. Medium-contact (or mixed) service is characterized by limited direct contact with customers. Examples include bank branches, real estate firms, repair shops, and moving companies. Reducing the amount of direct contact allows the service provider to perform other tasks, some of which may involve other customers. Typically, service customization is reduced as direct contact is reduced.

Low contact. Low-contact service, also known as quasi-manufacturing, is characterized by the low level of direct contact with customers. Examples include mail-order stores, research laboratories, and the home offices of banks and real estate firms. In these situations, work is more standardized, with less customization of the work flow.

Consumer self-service. Some services can be standardized to the point that a customer can procure the service for him or herself, without any involvement with the service provider. Examples include automated teller machines at banks, pay-at-the-pump gasoline stations, and self-checkout registers at retail and grocery stores that use bar code scanners and accept credit and debit card payments. Office activities are not completely eliminated but may also be automated, as with certain financial transactions.

Manufacturing support services. The following are categories of services that are the most relevant to the support of manufacturing operations:

- **Professional** services include engineering, accounting, medical, and legal. In production environments, engineering services are used to design products and production facilities. Cost accounting becomes important in price setting and maintaining operating margins. Legal services manage patents, copyrights, and contract development. They are considered support services in that they are not directly involved in production activities, unless they are part of an organization where their specialties are the primary service offered.
- **Trade** services are typified by construction and maintenance services and often are associated with unions. Electricians, plumbers, welders, machinists, carpenters, and other similar roles are highly specific in nature. Union groups, such as autoworkers or communications workers, may encompass several trades when forming bargaining units of related trades.
- **Delivery** services include setup and make-ready work. These initial tasks ensure that products are operating correctly and are ready for customers. Setting operating parameters, adjusting equipment, and other work necessary to get equipment into production also falls into this category.
- **Warranty** work occurs when a product fails. Warranty work can be done as field maintenance or may require the item to be shipped to a depot to be repaired. In some cases, the work can be performed remotely as the failed item is connected to diagnostic equipment via telecommunications.
- **Maintenance** services occur throughout the production cycle to keep equipment working. Maintenance services may be performed as warranty work and may be required to be performed on a specific schedule by qualified individuals in order to retain warranty protections. Maintenance can be performed by in-house staff or can be outsourced. These services are critical to the availability of production systems. Maintenance is performed at three levels.

    1. **Corrective maintenance**, sometimes referred to as break-fix maintenance, repairs equipment after a breakdown occurs. The time required to complete corrective maintenance directly impacts the availability of equipment after a failure. This maintenance service is critical when a run-to-failure operating philosophy is used.

    2. **Preventive maintenance** includes lubrication, replacement of worn parts, and other adjustments. Preventive maintenance forestalls equipment failure. Normal preventive maintenance inspections are performed on a regular schedule coordinated with the production schedule. Many of these inspections are performed during changeovers as a way to reduce downtime.

    3. **Predictive maintenance** anticipates failures and takes timely action to avoid them. Techniques, such as testing trace metals in the oil of jet engines, can pinpoint potential failures and allow operators to foresee problems before they occur, averting the need for later corrective maintenance. Predictive maintenance enables planners to schedule equipment outages to avoid unscheduled downtime by preventing failures from occurring.

4.3.2 Service system design matrix

The relationship between production efficiency and sales opportunities can be defined in a matrix that considers the degree of contact between customers and service providers. As direct contact between the customer and service provider increases, so do sales opportunities, typically at the expense of production efficiency. Conversely, when the service provider and customer have very little direct contact, sales opportunities are reduced but production efficiency increases.

A service system design matrix orders levels of contact in terms of increasing contact—from mail, to phone, to face-to-face. In the matrix, production efficiency is defined as the number of customers served over a specified period.

4.3.3 Service blueprints

A service blueprint is a flowcharting technique that allows service designers to identify the tasks involved in the service delivery system, isolate potential failure points in the system, establish delivery time frames, and set standards for each step that can be quantified for measurement. When developing service blueprints, special attention is given to the location of service providers relative to the customer. Blueprints recognize front room (direct) and back room (indirect) customer contact actions.

4.3.4 Queuing

How long a customer waits in line can be described mathematically with queuing models. Variables such as the rate customers enter the service system, the number of lines available, the average time spent with a service provider for each customer, and other probability factors can be used in mathematical models to determine expected wait times for each customer for various sets of assumptions. Queuing models are useful for the design and scheduling of waiting-line-type processes.

4.3.5 Service quality

In service, the assessment of quality typically is made during delivery. Each instance of customer contact is referred to as a moment of truth—an opportunity to satisfy or dissatisfy the customer. The customer compares the perception of quality received with expectation of service desired. Dimensions of service quality include reliability, responsiveness, timeliness, courtesy, assurance (trust and confidence in the service provider), empathy, and the appearance of the facility and personnel. Standard techniques are used to analyze and control quality in service processes, such as capability analysis, control charts, histograms, and fishbone diagrams. A service guarantee can define the meaning of service by setting standards of quality.

4.4 Quality

In operations management, quality has two major components: quality of conformance, or the quality defined by the absence of defects; and quality of design, or the quality measured by the degree of customer satisfaction with a product's characteristics and features.

4.4.1 Cost of quality

Costs of quality reflect the overall costs associated with prevention activities and the improvement of quality throughout the firm in all phases of the production of a product. These costs fall into four recognized categories: internal failures, external failures, appraisal costs, and prevention costs.

4.4.2 Principal theorists

W. Edwards Deming. Deming developed theories and concepts applicable to quality management and statistical quality control, first in Japan and later in the United States. Deming is credited as one of the fathers of the philosophy widely referred as total quality management.

Kaoru Ishikawa. Ishikawa was a Japanese philosopher and professor. In 1950, he developed the cause-and-effect diagram (also called the fishbone diagram or Ishikawa diagram). This diagram starts with the end result (the effect) and attempts to trace the causes of quality problems back from that point.

Joseph M. Juran. Juran, along with Deming, introduced statistical quality control (SQC) techniques in Japan and subsequently the United States. SQC is the application of statistical techniques to control quality, and includes concepts associated with acceptance sampling.

4.4.3 Total quality management (TQM)

TQM is an approach to improving quality and ultimately customer satisfaction. The term was first used to describe Japanese-style management approaches to quality management. It relies on the participation of all members of the organization. The methods of implementing this approach are found in the works of Armand Feigenbaum, Philip Crosby, W. Edwards Deming, Joseph M. Juran, Kaoru Ishikawa, and others. The overall goals of TQM are lower costs, higher revenues, satisfied customers, and empowered employees.

4.4.4 Six sigma

Six sigma is a methodology that emphasizes reducing process variability and product deficiencies to improve product quality and customer satisfaction. In the theory, at a six sigma level of performance, only 3.4 defects occur for every one million opportunities, assuming the process is operating within 1.5 standard deviations of the center of the process specification.

.1 Quality improvement tools

Kaoru Ishikawa, a principal theorist in quality improvement, stated that as much as 95 percent of all quality issues in the factory can be solved with seven fundamental quality tools: (1) flowcharts, (2) Pareto charts, (3) cause-and-effect diagrams, (4) control charts, (5) check sheets, (6) scatter diagrams, and (7) histograms.

.2 Continuous improvement

Continuous improvement means an ongoing effort to expose and eliminate the root

causes of problems, which leads to incremental improvements over time.

In six sigma, the improvement process has five stages. The stages are grouped collectively as the acronym DMAIC:

- **Define** the nature of the problem.
- **Measure** the existing performance and record data and facts that offer information to determine the root causes of the problem.
- **Analyze** the information to determine the root causes of the problem.
- **Improve** the process by implementing solutions to the problem.
- **Control** the process until the solutions become ingrained.

4.4.5 Business process reengineering (BPR)

BPR is the fundamental rethinking and radical redesign of business processes to achieve dramatic organizational improvements in critical measures of performance, such as cost, quality, service, and speed. The goal of BPR is to eliminate non-value-added activities, sometimes achieving these results through automation.

4.4.6 Statistical techniques

Statistical techniques are used to study and understand variations in processes and populations, interactions among these variables, and operational definitions. The ultimate goal is reducing variation in a process or population.

.1 Normal distribution

In this statistical distribution, most observations fall within one standard deviation (a measure of dispersion) from the mean, the measure of central tendency. In a normal distribution, observations are equally likely to be greater or less than the mean, as the dispersion is symmetrical. When graphed, the normal distribution takes the form of a bell-shaped curve.

.2 Process capability

Process capability is the ability of a process to produce parts that conform to engineering specifications. Process capability deals with the inherent variability of a process in a state of statistical control and its relationship to design tolerances. Measures of process capability have the notations Cp and Cpk. Cp considers both sides of the mean. Cpk relates to either side of the mean, but not both.

.3 Statistical process control (SPC)

SPC is the application of statistical techniques to control quality. Sometimes the term is used interchangeably with statistical quality control (or is considered the main subset of statistical quality control).

Variable data. Variable, or quantitative, data take the form of numerical values and arise from measuring a characteristic of a product, service, or process; or from the computation of two or more measurements. There are no set categories or values that variable data can take. Heights and weights are examples of variable data.

Attribute data. Attribute data take form from the classification of items, such as products or services, into categories. Alternatively, they may be represented by counts or proportions of items in a given category or counts of occurrences per unit. Some examples of attribute data are found in binary categories, such as go/no-go information and the reporting of gender.

Chart types. Control charts are graphical comparisons of process performance data with predetermined control limits. The data usually consist of samples of a fixed size selected at regular intervals. Control charts are used primarily to detect assignable causes of variation in processes and rule out random variations. The most common control charts are the X-bar chart (used to track sample means) and the c chart (used to track attribute defects).

.4 Average outgoing quality (AOQ)

AOQ is the expected average quality level of outgoing product for a given value of incoming product quality.

.5 Acceptance sampling

Acceptance sampling typically is used for determining whether a batch of parts conform to a quality specification. This is executed through a sampling process in which the number of units in the sample and the maximum number of defective items are defined. If defects exceed the maximum acceptable amount, the entire batch is rejected.

4.4.7 Benchmarking and best practices

Benchmarking is the continuous process of measuring products, services, costs, and practices. The two types of benchmarking are competitive (a comparison against the industry best) and process (a comparison to the best in class). Best practices, through the benchmarking process, identify opportunities for improvement. The process of comparing a result to a best practice may be applied to resources, activities, and costs.

4.4.8 ISO registration

The standards issued by the Belgium-based organization ISO, whose English name is the International Organization of Standardization, have been adopted by more than 100 nations and are supported by most national standards organizations.

ISO 9000 is a set of five related international standards on quality management and assurance, developed to help companies document the elements needed to maintain an efficient quality system.

CHAPTER 5

Planning and Control

Planning and control processes are the closed-loop processes that determine the need for material and capacity to address expected demand, execute the resulting plans, and update planning and financial information to reflect the results of execution. Planning and control processes exist at several levels: The most common are business planning, sales and operations planning, master scheduling, material requirements planning, production activity control, and project planning. Each level addresses different decision-making needs, covers a planning horizon, and is stated in units appropriate for the level. The highest level addresses long-term needs, such as the decision to build facilities. The lowest level addresses short-term needs, such as deciding which of two waiting jobs should be run through an assembly process first.

Each level produces two types of plans. The first is for the delivery of that level's focus (the focus plan), and the second is for providing the capacity and capability needed to support that delivery (the support plan). The importance of the two types depend on the nature of the business. For example, a service business might be more concerned with a robust staffing plan (support), and a manufacturing business might be more concerned with a robust production schedule (focus). The most common levels of planning are summarized in the following table.

Process	Focus plan	Support plan	Time horizon	Focus plan units
Business planning (strategic planning)	Revenue plan	Spending plan	Very long	Financial (dollars)
Sales and operations planning	Production plan	Resource plan	Long	Product and service lines (dollars of revenue)
Master scheduling	Master production schedule	Rough-cut capacity plan	Medium	End-level product numbers
Manufacturing resource planning (MRP II)	Material requirements plan/ planned and scheduled orders	Capacity requirements plan	Medium	Part numbers (end-level, internal processed, purchased)
Production activity control (shop floor control)	Production schedule/ dispatch list/released orders	Staffing plan, input/output control	Short	In-process parts (part numbers and operation numbers)
Portfolio/program/ project planning (single products and services)	Project schedule/deliverables/ work breakdown structure	Resource plan (staffing and material)	Comprehensive (very long through short)	Varies (schedule, dollars, percent complete, project indexes)

5.1 Enterprise resources planning (ERP)

ERP is a framework for planning all of the resources of a business, from strategic planning through execution. Information technology tools and software can automate process links, sharing information across functional areas and processing business transactions efficiently. ERP systems also support the organization of data for decision making and analysis, and are typically organized around modules that support functional areas such as finance, marketing, human resources, operations, purchasing, and logistics. Real-time sharing of data is enabled by using a common database across these modules. (See section 8.1.1.)

5.2 Inventory

Inventory is listed as an asset on a firm's balance sheet and consists of the stocks or items needed to maintain production, support activities such as maintenance and repair, and provide customer service. Inventory typically is categorized based on its flow through the production cycle, using such designations as raw materials, work in process, and finished goods. Maintenance, repair, and operating supplies also are stocked to support the functionality of the firm.

For planning and forecasting purposes, inventory is classified based on the source of its demand as either independent or dependent. Independent demand items are requested directly by the customer and thus must be forecasted. Demand for dependent items can be derived or calculated based on relationships to independent items, usually noted by higher levels in the bill of material.

5.2.1 Purpose of inventory

Inventory's primary purpose is to meet demand in support of production or customer service. Inventory is an expensive asset and needs to be carefully managed and controlled. The following terms are related to the different purposes of inventory.

Pipeline. Pipeline is inventory in the transportation network, including inventory shipped from a supplier but not yet received by the customer. The overall network design impacts the amount of pipeline inventory.

Cycle stock. Cycle stock typically is the most active inventory component. Its amount is based on lot-sizing rules as stocks are received and depleted.

Anticipation. Anticipation is the stocking of additional inventory to cover projected trends of increased demand from forecasted events such as sales promotions, seasonal fluctuations, plant shutdowns, vacations, supplier price increases, and possibilities of labor disruptions.

Decoupling. Decoupling is creating independence between supply and the use of material. It refers to inventory that often is collected between operations so that fluctuations in the production rate of the supplying operations do not limit the output of the next operation.

Safety stock. Safety stock is inventory carried in excess of expectations used to cushion against uncertainty in demand or in replenishment lead time.

Hedging. Hedging is purchasing inventory in advance to mitigate the impact of anticipated price increases or shortages.

Obsolescence. A critical condition in inventory management is keeping inventory in up-to-date, usable condition. Inventory that becomes obsolete typically becomes a write-off against profits on the profit and loss statement. Obsolescence can occur from effects such as spoilage, as in food; and loss of utility from the introduction of better or more economical products, methods, and facilities.

5.2.2 Inventory types

Inventory is a broad term. In service industries, it might mean classifications of worker skills and positions or repair equipment. In most fields, it also can refer to the equipment, fixtures, buildings, and materials used in production.

Raw materials. Raw materials require added value or labor to be converted into useable parts. The generally accepted accounting principles view of raw materials is as purchased items or extracted materials that are converted into components and products through manufacturing.

Work in process (WIP). WIP refers to goods in various stages of completion, including all material that has been released for initial processing and processed material awaiting final inspection. A value-added process applied to a raw material is considered WIP.

Finished goods. Finished goods are those on which all manufacturing or service operations have been completed. They are products available for delivery to the customer.

Distribution. Distribution refers to inventory located in the distribution system that is separate from manufacturing inventory. It includes items in transit and items in storage awaiting delivery to a customer.

Maintenance, repair, and operating supplies (MRO). MRO refers to items used to support general operations and maintenance (such as spare parts) and consumables used in the manufacturing process and supporting operations. In terms of dollars and quantity, this inventory is considered relatively minor; but in continuous process and flow industries, it may equal or exceed production inventory. Failure to have basic office supplies or a spare part when needed can be harmful to the profitability of a firm.

Service parts. Service parts are modules, kits, components, and individual parts used to replace an original without modification. Service parts usually are a segment of distribution inventory. Some firms, such as automotive original equipment manufacturers, are required by law to provide replacement inventory for vehicles years after sale.

5.2.3 Push systems and pull systems

Push systems. In a push system, items are produced on a schedule in advance of customer need. In material control, issuing material according to a schedule or to a

job at its start time are hallmarks of a push system.

Pull systems. In a pull system, items are produced only as demanded for use or to replace items taken for use. In material control, pull systems withdraw inventory as demanded by operations. Kanban signals enable actual demand or usage to initiate the flow of materials. (See section 6.5.4.)

Push-pull boundary. Some businesses use both push and pull systems within the same facility. The push-pull boundary is the point where one system ends and the other takes over.

5.2.4 Customer order decoupling point

This is a point where inventory is carried to buffer at least part of the manufacturing system from individual customer orders. The selection of decoupling points is a strategic decision that determines customer lead times and inventory investment.

5.2.5 Lean concepts

See section 3.11.

5.3 Master planning

Master planning refers to a group of business processes that includes demand management, sales and operations planning, and master production scheduling. In each level of master planning, demand is forecasted and methods are formulated to meet the demand, given capacity constraints. Master planning, along with capacity requirements planning and material requirements planning, together comprise an integrated system called manufacturing resource planning (MRP II). When further linked with financial, project management, and other common enterprise processes, they comprise the system called enterprise resources planning. (See section 5.1.)

5.4 Demand management and forecasting

Demand management and forecasting is recognizing all demand for goods and services to support the marketplace. Demand is prioritized when supply is lacking. Proper demand management facilitates the planning and use of resources for positive and profitable results and may involve marketing programs designed to increase or reduce demand in a relatively short time.

5.4.1 Planning horizon

The planning horizon is how far a plan extends into the future and is dictated by tactical and strategic degrees of uncertainty. The tactical horizon may be based on the cumulative lead time needed to procure or produce low-level components. The strategic horizon is based on the time needed to adjust capacity. A greater degree of uncertainty requires a longer planning horizon.

5.4.2 Forecasting

Forecasting is attempting to predict or project future statistics—typically, demand or sales. It requires that all factors surrounding the decision-making process are recorded. Factors that affect forecasting include sales demand patterns, economic conditions, competitor actions, market research, product mixes, and pricing and promotional

activities. Forecasts can be made at strategic, tactical, and operational levels.

.1 Types of forecasts

Forecasts can be categorized by technique, such as subjective, causal, and time-series. Subjective forecasting is a qualitative technique, while the causal and time series methods are quantitative, statistical models.

.2 Forecasting process

The forecasting process predicts demand and the use of products and services so that the right quantities are ordered in advance. In forecasting, either historical demand data are transformed into future projections or a subjective prediction of the future is made—or some combination of the two.

.3 Pyramid forecasting

Pyramid forecasting, or rationalizing high- and low-level forecasts, enables management to review and adjust forecasts made at an aggregate level and keep lower-level forecasts balanced. In the process, item forecasts first are aggregated by product group. Management then makes a new forecast for the group. The value is then transferred to individual item forecasts so that they are consistent with the aggregate plan.

.4 Forecasting models

Many models are used to predict demand, such as regression analysis, time series, the Delphi method, and market research—or some combination of these quantitative and qualitative methods. Forecast data may be broken down in an attempt to uncover the components of demand, such as trend, seasonality, and cyclical and random patterns. The base component reflects the demand for an item without applying the patterns.

Baseline methods. Baseline demand is the percentage of a company's demand derived from continuing contracts and existing customers. It usually is a predictable component of demand.

Time series. Time series is a technique that projects historical data patterns by looking at past forecasts and forecast errors. A time series may contain seasonal, cyclical, trend, and random components.

Exponential smoothing. Exponential smoothing is a forecasting technique using a weighted moving average, where past observations are adjusted according to their age. The most recent data typically are weighted the heaviest. A smoothing constant is applied to the difference between the most recent forecast and critical sales data, avoiding the necessity of maintaining historical sales data. Alternatives to exponential smoothing include moving average and weighted moving average models.

Trend. Trend is the general upward or downward movement of demand over time.

Seasonality. Seasonality is a cyclical pattern of demand, where some periods of the year are higher or lower than others.

Regression models. Regression models are statistical techniques used to determine the best mathematical expression that describes the relationship between a dependent

variable, such as demand, and one or more independent variables.

Focus forecasting. Focus forecasting is a system that allows a user to simulate the effectiveness of numerous forecasting techniques and select the best method.

.5 Error measurement

Error is the difference between a forecast and the actual demand.

Bias. Bias refers to consistent errors that cause a forecast to go either too high or too low. A forecast is biased if the current forecast errors are greater or less than zero.

Standard deviation. Standard deviation is a measurement of the dispersion of data or of a variable. It is calculated by finding the differences between average and actual observations, squaring each difference, adding the squared differences, dividing by n minus 1 (for a sample), and finally taking the square root of the result.

Mean absolute deviation (MAD). MAD is the average of the absolute values of the deviations of observed values from forecast values. It is the arithmetic mean of past absolute errors.

Mean absolute percent error. Mean absolute percent error is computed by taking the MAD, dividing by the average demand, and then multiplying by 100.

Tracking signal. Tracking signal refers to the ratio of the cumulative algebraic sum of the deviation between forecasts and actual values to the mean absolute deviation. This is used to alert that the forecast model is biased.

.6 Special situations

Some situations impact forecast accuracy by creating unique circumstances that change demand.

Promotions and de-promotions. These are products subject to wide fluctuations in sales, often being sold at a reduced price or as part of another sales incentive.

Cannibalization. Cannibalization is the reduction of demand for a product due to the introduction of a new or similar product.

Substitution. Substitution is the use of a different product or component not originally specified on an order but serving the same purpose, which impacts demand history.

.7 Data warehouses

Data warehouses are repositories of data specially prepared to support decision-making applications. In forecasting, they are where quantitative and qualitative data are collected for future needs.

.8 Matching methods and uses

Each forecasting method has a unique set of characteristics and applies differently to specific situations. For example, exponential smoothing might be appropriate for a very short-term forecast predicting demand during lead time, but not for a long-term

product group demand forecast (where regression might be a better fit). Selecting the best method or methods for specific needs is important in successful forecasting.

5.5 Sales and operations planning (S&OP)

S&OP develops a midrange plan to operations using input from top management. The plan identifies key resources to achieve the firm's strategic objectives and goals, and is the basis of all subsequent material and labor resource decisions and for the master production schedule).

5.5.1 Business planning

This is the process of creating the business plan, which identifies the organizational, strategic, and financial goals of the firm. It is a statement of long-range revenue, cost, and profit objectives and long-range strategy, usually accompanied by budgets, a projected balance sheet, and a cash flow statement. The business plan is stated in terms of dollars and grouped by product families. It is an input to the S&OP process.

5.5.2 Sources/output process participants

Participants include personnel from various areas of operations, finance, human resources, purchasing, materials, transportation, engineering, and quality.

5.5.3 S&OP process

The S&OP process develops tactical plans that assist management in strategically directing the business to achieve continuous competitive advantage. It integrates customer-focused marketing plans for new and existing products with the management of the supply chain. The process integrates all business plans into a single set that meets all needs of the functions of the business. The S&OP process is performed at least once a month and is reviewed by management at an aggregate level.

5.5.4 Aggregate planning strategies

Aggregate planning strategies are manufacturing strategies for meeting customer demand by setting production levels, inventory levels, and backlog. They can include the following methods:

- **Chase** methods match the production rate to the order rate by adjusting capacity. A mix of permanent and temporary workers typically are used with this strategy.
- **Level** methods maintain a stable capacity with a constant output rate. Shortages and surpluses are absorbed by fluctuating inventory levels, order backlogs, and lost sales.
- **Hybrid** methods combine aspects of both chase and level methods. Overtime, undertime, and flexible work schedules often are used with hybrid methods.

5.5.5 Management of supply and demand

Management of supply and demand is accounting for demand variability by providing adequate supply capacity and demand flexibility so that production rates match strategic objectives and goals.

Managing capacity. The four levels of managing capacity are resource planning, rough-cut capacity planning, capacity requirements planning, and input/output control. At each level, capacity is established, measured, monitored, and adjusted to execute operation schedules and meet the needs of the business plan. Capacity must be modified if the needs are not met. At the S&OP level, these adjustments can be made by hiring, subcontracting, and accepting stockouts. Each tactic has its own benefits and costs.

Managing inventory. Managing inventory is determining optimal inventory levels as they pertain to strategic objectives.

Managing demand. Managing demand is recognizing and interacting with demand sources. When supply is lacking, demand is prioritized; and pricing, promotions, and product distribution are closely monitored to determine impacts on the marketplace.

5.5.6 Disaggregating the plan

Disaggregating is the process of breaking apart the production plan from a monthly family and group projection to a weekly item product projection for the master production scheduling process.

5.5.7 Master scheduling

Master scheduling is the process in which the S&OP plan is disaggregated and the master production schedule is generated, reviewed, and adjusted to ensure consistency with the production plan.

.1 Bill-of-material structuring

The bill of material (BOM) is the document that specifies the components needed to produce a good or service. It lists the parts, raw materials, subassemblies, and intermediates required by a parent assembly. A BOM specifies the quantity required to make one item, specifies units of measure, and quantifies phase-in and phase-out dating. Other names for the BOM are formula, parts list, and recipe or ingredient list.

Various forms of BOMs are used in master production scheduling and material requirements planning.

Traditional. Traditional BOMs list the subassemblies, intermediates, parts, and raw materials needed for a parent assembly, specifying the quantities of each. Types of these bills include single-level, multi-level, and engineered.

Planning. A planning bill is an artificial grouping of items or events in BOM format used to facilitate master scheduling and material planning. It may include the historical average of demand expressed as a percentage of total demand for all options within a feature or for a specific end item within a product family and is used as the quantity per in the planning bill of material.

Modular. Modular BOMs are planning bills arranged by product modules or product options that help facilitate material planning.

Add/delete bills. This is the process by which new components are added to, deleted from, or otherwise modified in a bill of material. An engineering change notice initiates the process, specifying the effective date to make the change on the bill.

Phantom bills. Phantom bills are a coding and structuring technique used primarily for transient subassemblies. The phantom bill represents an item that may not exist physically but is treated as an accounting unit.

Kitting parts. Kitting is listing related parts or components that can be mixed and matched into a bundle. The kitting BOM facilitates the assessment of material availability before order picking against a shop order or customer order.

Engineering change management. Engineering change management controls design changes released by the engineering department to modify or correct a bill of material. An engineering change review committee is assembled by management and determines the effective date and disposition of existing material.

.2 Master schedule

The master schedule is a list that includes the forecast, customer orders, times, projected available balances, available-to-promise, and the master production schedule. It is a relatively short-term schedule for meeting demand.

Projected available balance. The projected available balance is a prediction of future inventory balance. It is the running total of inventory on hand, minus requirements, plus scheduled and planned order receipts.

Available-to-promise (ATP). This is the uncommitted portion of a company's inventory and planned production maintained in the master schedule to support customer order promising. There are numerous methods of calculating ATP.

Capable-to-promise (CTP). CTP is the process of measuring orders against available capacity and inventory. CTP is used to determine when a new or unscheduled customer order can be delivered. The process may involve multiple manufacturing or distribution sites.

.3 Rough-cut capacity planning (RCCP)

RCCP is the process of converting the master production schedule into requirements for key resources, typically labor, machinery, warehouse space, supplier capabilities, and sometimes money. Each key resource usually is compared to available or demonstrated capacity.

Bill of resources. A bill of resources is a list of the required capacity and key resources needed to manufacture one unit of a selected item or family. Resource planning and RCCP both use a bill of resources to calculate the capacity requirements of the master production schedule.

Capacity planning. Capacity planning is determining the amount of capacity

required to produce a good or service in the future. RCCP will validate whether the master production schedule can be achieved.

Utilization. Capacity plans often are expressed in terms of utilization, or the percentage of available time that a resource will be used for its intended purpose.

Efficiency. Efficiency is the measure of the utilization of a capacity resource compared to its best possible utilization.

5.6 Material requirements planning (MRP)

MRP is a set of techniques that uses bill of material data, inventory data, and the master production schedule to calculate requirements for materials. MRP makes recommendations to release replenishment orders for material.

5.6.1 Data requirements (upstream and downstream integration)

MRP calculates requirements based on higher-level requirements derived from sales and operations planning and master production schedule processes. This facilitates increased communication and coordination between all parties to identify and fulfill resource requirements based on established plans.

5.6.2 Explosion

Explosion, or requirements explosion, is the process of calculating demand for the components of a parent item by multiplying the parent item's requirements by the component usage quantity specified in the bill of material.

5.6.3 Pegging

Pegging is the ability to identify the sources of an item's gross requirements and allocations. Pegging is considered active, where-used information.

5.6.4 Lot-sizing models

Lot-sizing models are the techniques used in determining order or production run sizes.

Fixed order. Fixed order is a lot-sizing technique that generates planned or actual orders for a predetermined fixed quantity.

Discrete lot sizing. Discrete lot sizing is an order quantity with an integer number of periods of demand. Examples of these techniques include period order quantity, part period balancing, lot-for-lot, least total cost, and fixed-period requirements.

5.6.5 Production activity control (PAC)

PAC is the function of routing and dispatching work to be accomplished through the production facility and of performing supplier control. PAC encompasses the principles, approaches, and techniques needed to schedule, control, measure, and evaluate the effectiveness of production operations.

.1 Short-interval scheduling

Short-interval scheduling is a method of monitoring order quantity to minimize the queue, move, and wait times at a work center. It uses detailed operation time analysis to reduce production time and minimize batch size.

5.6.6 MRP/Just-in-Time (JIT) integration

.1 JIT planning

Integrating JIT with MRP requires an approach by which the ordering of components and parts is planned based on production rates to estimate future requirements. These plans would be executed using kanban or a similar pull system.

.2 Backflush

In backflush, component parts, material, and subassemblies are deducted from the inventory on hand by exploding the bill of material and multiplying the quantities of each required by the number of assemblies produced. Backflushing reduces the amount of data capturing and processing needed, but it requires system integrity, accurate reporting of completed items, accurate measuring of yield, and special reporting of unusual situations. Backflushing is especially appropriate for JIT environments, where pull systems are used.

5.7 Distribution requirements planning (DRP)

DRP determines the need to replenish inventory at branch warehouses. A time-phased order point approach is used where the planned orders at the branch warehouse level are exploded via material requirements planning logic to become gross requirements on the supplying source. The extension of DRP into the planning of key resources contained in a distribution system is called DRP II

5.7.1 Distribution inventories/independent demand

Distribution inventories, including finished goods and spare parts, involve items that customers might order. These inventories are either warehoused or in transit to customers. Distribution inventory management is important to supply chain management because of the global sourcing of parts and products. As more global sourcing is employed, transportation lead times increase and, consequently, inventory levels increase.

Independent demand is demand coming directly from the customer. Dependent demand, in contrast, is demand coming from a higher level in the bill of material. Independent demand is typically forecasted, while dependent demand is typically calculated. (See section 5.2.)

Independent demand drives the need for distribution inventory because customers want products or services when the need arises instead of waiting for inventory to be produced and moved through the entire supply chain. Independent demand primarily is associated with end user demand in supply chains. However, independent demand techniques and models also are used in manufacturing in several applications, including seasonal ordering, as ordering conventions with material requirements planning,

and other variable demand processes.

5.8 Inventory management

Inventory analysis techniques enable a business to manage the trade-off between having too much and not enough inventory on hand. The level of inventory held for independent demand items generally can be estimated by knowing how often inventory is replenished and how much safety stock is held. Cycle stock is the average amount of inventory held due to the periodic replenishment of inventory. Safety stock is the amount of extra inventory kept to reduce the risk of stockout. (See section 5.2.1.)

5.8.1 Turns and days of supply

These are metrics that describe how quickly inventory moves through the organization and through the supply chain. They help manage inventory balances from period to period and assess the impact inventory has on financial statements and customer service.

5.8.2 Cash-to-cash cycle time

This metric is measured in terms of days and describes how long the company or supply chain takes to recover the expenses incurred when buying material, paying labor costs, or otherwise incurring overhead.

5.9 Inventory models

Once items are shipped through the distribution network, inventory is replenished. This is especially true for make-to-stock situations. (See section 4.2.2.) Several models are available to help determine how much inventory should be brought in to restock the products or parts.

5.9.1 Single-period ordering

Single-period ordering occurs when an item is purchased one time, such as a daily newspaper purchase or holiday season order. This method balances the trade-off associated with an insufficient order (and the resulting loss in profit) and ordering too much (and the resulting costs of disposing of the excess).

5.9.2 Economic order quantity (EOQ)

EOQ is a formula-driven lot-sizing method that balances the trade-off between carrying costs and ordering costs. EOQ is most useful for repetitive parts with stable demand to determine how much to buy. Companies might use EOQ as a check on their current lot-sizing methods. EOQ has numerous variations. (See section 3.11.6.)

5.9.3 Replenishment models

Distribution inventories and independent demand environments use different types of replenishment models based on dependent demand situations.

Reorder point. A reorder point is calculated for each independent demand item. When inventory levels drop to the reorder point, a signal is sent to replenish inventory

in a fixed quantity amount. The reorder point is equal to the expected demand during lead time plus safety stock to cover demand in excess of expectations.

Periodic review. A periodic review occurs when inventory is ordered at fixed intervals, such as weekly. This is desirable when vendors make routine visits to customers and take orders for a complete line of products, or when buyers want to combine orders to save transportation costs. The order quantity is determined by subtracting the current inventory position from a maximum quantity calculated to protect against stockouts during the review period and lead time.

Safety calculations. Safety stock for independent demand items protects against fluctuations in customer demand. Safety stock calculations use statistics to mitigate the risk of stockout. A service criterion measures risk as the probability of not stocking out during the order cycle. The fill rate criterion measures risk as a function of the expected percentage of demand met.

Normal distribution. The normal distribution can be used to characterize independent demand. It is defined by the mean and standard deviation of demand over a specified period of time to help calculate safety stock in inventory control systems.

5.9.4 Quantity discounts/price breaks/promotions

Purchasing decisions often are influenced by quantity discounts, price breaks and other promotions. Specialized techniques help analyze these decisions by considering trade-offs between purchasing and transporting costs, inventory carrying costs, and fixed ordering costs.

5.9.5 Low-volume items

Specialized techniques and distributions may be required for low-volume items, since the normal distribution assumption might not be applicable.

5.9.6 ABC inventory control

ABC inventory control is a method of ranking items by their importance, as focusing on the most important items is crucial when resources are limited. Criteria for determining item importance in include annual cost, annual usage, revenue generated, and usage by priority customers. In a typical situation, about 20 percent of items make up 80 percent of the yearly cost and become A items. Another 30 percent of the items make up 15 percent of the cost and become B items. C items make up the remaining 50 percent of items and consume only the remaining 5 percent of the cost. In ABC inventory control, A items are carefully managed and ordered frequently to minimize investment; less time and resources are devoted to the B items; a very low amount of time and resources are dedicated to the C items.

ABC Inventory control also is used in cycle counting. For example, the A items are counted often—once per month, for example. The B items are counted less often—once per calendar quarter, for example. The C items may be counted even less often—once per year, for example.

5.9.7 Inventory accuracy

High inventory accuracy is mandatory for optimal operation of production and automated systems. The inventory physically located in distribution must be reflected accurately in the system. Due to the automation and integration of enterprise resources planning (ERP) systems, inventory is linked to other functions within a company, such as the tracking of dollars in accounting for inventory receipts and shipments. ERP implementation demands inventory accuracies as high as 99 percent.

Auditing. Along with maintaining peak operational functionality, another reason distribution inventories must be kept accurate is to satisfy accounting and government reporting requirements. In order to comply with these strict practices, some companies choose to audit their inventories. In an audit, stocks of a particular item are counted and compared to a system balance. If an inaccuracy is found, the system is adjusted.

Cycle counting. Cycle counting takes the audit concept one step further. In cycle counting, after an audit is performed, the cycle counting process will search for a root cause for the inaccuracy. Once resolved, inventory accuracy is increased, because the problem will not reoccur for that item and other items affected by the improvement.

Some companies will work alongside finance and implement a cycle counting schedule similar to an ABC inventory control process. This type of counting schedule works best when inventory physically resides in fixed locations. Lean distribution environments work towards eliminating cycle counting and annual physical inventory counts, as inventory levels are minimized. Some organizations can eliminate cycle counting entirely, if high inventory accuracy can be demonstrated without cycle counting.

5.9.8 Pooling inventory

In a multiple-warehouse distribution architecture, decisions as to where items are warehoused are of particular importance. Stocking every item in every warehouse often is not required. Pooling strategies are employed when items have highly variable demand in certain warehouses. If inventory can be consolidated in a centralized warehouse rather than stocked in all warehouses, the variability of customer demand will be reduced. However, this strategy may result in longer delivery lead times and increased expediting and shipping costs.

5.9.9 Postponement

Postponement strategies delay the completion of assembly at some point in the supply chain until the customer order is received.

5.10 Vendor-managed inventory (VMI)

VMI partnerships occur when downstream supply chain customers choose to partner with their suppliers. Agreements are made as to where the inventory is stored (either at the supplier's site or the customer's site) and when the billing for the inventory will take place (either upon shipment to the customer or upon use of the part). Further, the supplier often will take control of managing inventory levels for the customer. In some cases, a customer representative may be located at the supplier's site to help manage the activity (or vice versa, as in a retail store). Potential advantages to the supply chain are that transactions are automated and redundancies in paperwork are reduced.

5.11 Collaborative planning, forecasting, and replenishment (CPFR)

CPFR is a supply chain strategy in which members of the supply chain work towards best practices in planning the flow of production from the first link in the chain to the last link in the chain. CPFR for distribution inventories may involve planning for such activities as replenishment, vendor-managed inventory, forecasting, assortment optimization, retail store clustering, and presentation stock. (See section 3.9.3.)

CHAPTER 6

Scheduling

6.1 Routing

The routing file contains a record for each manufactured part and identifies the sequential operations and work centers required to manufacture the part, standards for setup and run, and any required tooling. Key work center items include descriptive data, calculation requirements, shop calendar and use, and efficiency factors. A manufacturing shop calendar is used in inventory and production planning functions, enabling a schedule for component and work order scheduling based on the actual number of work days available.

6.2 Standard time

Standard time is the established norm of productivity. It is the length of time that should be required to set up a given machine or operation and run one batch or one or more parts, assemblies, or end products through that operation. The norm is then used to measure against actual results.

6.3 Scheduling techniques

Various scheduling techniques are used for determining how to define and control capacity and load.

Finite scheduling. Finite scheduling is assigning no more work to a work center than it can be expected to execute in a given period.

Infinite scheduling. Infinite scheduling involves calculating the capacity required at work centers in each period to run a schedule that was developed without regard to actual capacity.

Forward scheduling. Forward scheduling involves scheduling work starting on the planned release date or the current date and determining the future completion date.

Backward scheduling. Backward scheduling involves scheduling from the customer's planned receipt date and moves backward in time to determine the start date of the work.

6.4 Master production schedule (MPS) and final assembly schedule (FAS)

The MPS is a line on the master schedule grid reflecting the anticipated build schedule of those items assigned to it. It represents the items the company plans to produce expressed in specific configurations, quantities, and dates. The FAS is used to drive the staging of components and parts to feed an assembly line, where each item has unique options specific to individual customer orders. (See section 5.5.7.)

6.5 Dispatching

Dispatching is the selection and sequencing of available jobs for individual workstations and the assignment of those jobs to workers. Dispatching also can refer to the loading and scheduling of trucks to meet shipment objectives.

6.5.1 Priority rules

Priority rules, sometimes called dispatching rules, are the specific instructions for assigning priorities to jobs at a work center. Some commonly used rules are first come, first served; earliest job due date; earliest operation due date; and shortest processing time.

6.5.2 Critical ratio

Critical ratio is a special type of priority rule that uses current status information and calculates a priority index number by dividing the time to a job's due date by the expected elapsed time to finish the job.

6.5.3 Input/output control (I/O)

I/O is a technique for capacity control that monitors planned and actual inputs and outputs of a work center.

6.5.4 Kanban

Kanban is a method of Just-in-Time production that uses standard containers or lot sizes with a single card attached to each. It is a pull system in which work centers signal with a card that they wish to withdraw parts from feeding operations or suppliers, indicating the need to replenish or produce more. A second card may be used to signal the movement of material.

6.6 Queuing and simulation

A queue is a waiting line of work needing to be processed. Simple queues can be analyzed with queuing models to estimate waiting time and queue length. More complex situations are analyzed using simulations. Simulation is a technique in which systems are modeled using a computer program designed to mimic a real system. Simulations may be run before a real system becomes operational to aid in design, to see how the system might react to changes in operating rules, and to evaluate the system's response to changes in its structure.

6.7 Theory of constraints (TOC)

TOC focuses on four key concepts: constraints, drum, buffer, and the rope. Managing constraints is critical to the process. In the process, the pace of the line operation is set by the speed of the constraint, an inventory buffer is placed before the constraint to protect the pace, and inventory is pulled through the line based on customer order input, which minimizes inventory and speeds the entire production process.

6.8 Service scheduling (days on/days off)

Service scheduling is scheduling by number of employees and shifts to maintain a capacity level that can meet anticipated demand. Considerations include employee skill mix, shift assignments, and employee preferences.

6.9 Advanced planning and scheduling (APS)

APS describes a computer program that uses advanced mathematical algorithms and logic to perform optimization or simulation to solve scheduling problems. These techniques simultaneously consider a range of constraints and business rules and provide planning, scheduling, and decision support.

6.10 Production activity control (PAC)

PAC is the function of routing and dispatching work to be accomplished through the production facility and of performing supplier control.

See section 5.6.5.

6.10.1 Short-interval scheduling

Short-interval scheduling is a method to minimize the short-term queue, or move and wait times at a work center, by monitoring the work arriving at a work center. (See section 5.6.5.1.)

6.10.2 Input/output control

See section 6.5.3.

6.11 Manufacturing execution systems management

This refers to programs that guide workstation activities and capture detailed related information in real time.

6.11.1 Tracking

Tracking is the process of tracing the movement of material, labor, and work orders from issuance through work order movement.

Component traceability. Component traceability is registering and tracking parts, processes, and material used in production by lot or serial number.

Productivity. Productivity is the overall measure of the ability to produce a good or a service. It is found by comparing actual output of production to actual input of resources. Productivity is a relative measure across time or against common entities.

Product integrity. Product integrity is producing a product that meets its stated intention, delivering the product on time, and working with customers to resolve questions or issues.

Accountability. Accountability is being answerable for, although not necessarily personally charged with, doing work. Accountability cannot be delegated, but it can be changed.

CHAPTER 7

Project Management

Project management is using skills and knowledge for organizing, planning, scheduling, directing, controlling, monitoring, and evaluating the prescribed activities needed to complete a large-scale task.

7.1 Project organization and leadership

Before a project starts, senior management decides how the project will be organized. Three basic approaches are available: pure project, functional project, and matrix project.

Pure project. In pure-project approaches, a self-contained team works on the project full time.

Functional project. A functional project is housed within a functional division of the firm and specialized function-area experts work on the project.

Matrix project. A matrix project blends properties of functional and pure-project structures. Each project uses people from different functional areas. The project manager coordinates activities of the project while working closely with functional managers.

7.2 Planning processes

Planning processes start with the project concept phase, in which a broad definition of the project is created. A detailed-definition phase is next, in which more specific parameters of the project are explored: what, who, how, when, and how much. Following this is an activities-and-targets phase, during which specific goals, milestones, and cost targets are established. Actual activities are then implemented in the performance phase. The last phase, the post-completion phase, is an ongoing state for the organization. In this stage, continual-goal assessments and other metrics are used by decision makers to track the level of success of the project.

- **Evaluation and selection of project.** Projects often are selected from a portfolio of potential endeavors. They are evaluated based on potential impact to the firm, usually based on cost reduction or profit.

- **Alignment of projects with strategy.** Project goals and objectives need to be determined to support the strategy of the firm.

7.2.1 Gantt chart

A Gantt chart represents the activities of the project, displaying start times and completion times on the horizontal axis. This simple presentation gives an overview of project status at a glance; however, it does not show the interaction of project activities.

7.2.2 Network diagrams

Network diagrams are graphical representations of the precedence linkages of tasks in a project, generally made up of nodes and arrows. Network diagrams are either activity-on-node or activity-on-arrow. In activity-on-node diagrams, which are more common, arrows linking nodes are indications of relationships rather than time.

7.2.3 Critical path method (CPM)

CPM is a technique for the analysis of a project's completion time used for planning and controlling a project's activities. The critical path, which identifies elements that constrain the total time for a project, can be determined by examining each activity and its associated discrete time. Early start, late start, early finish, and late finish times also are calculated for each activity.

7.2.4 Program evaluation and review technique (PERT)

PERT, also known as probabilistic scheduling, is a network analysis technique where each activity is assigned a pessimistic, a most likely, and an optimistic estimate of its duration. The critical path method is then applied, using a weighted average of the three times for each node. PERT computes a mean and standard deviation of the project duration, facilitating the assignment of probabilities for completion time.

7.2.5 Crashing

Crashing is adding resources to critical path or near-critical path activities on a project to shorten a project's duration after identifying the most cost-effective course of action. When the reallocation of resources towards the critical path will have no further effect on shortening overall project time, a project is considered fully "crashed." Crashing may stop before all possible activities have been altered, based on the trade-off of the added expense to shorten the activity versus the opportunity cost of having the resources already committed.

7.2.6 Resource-limited scheduling

In this technique, activities are scheduled so that predetermined resource availability pools are not exceeded. Activities begin as soon as resources are available (with respect to logical constraints). When not enough of a particular resource exists to perform all tasks on a given day, a priority decision is made. Project completion may be delayed, if necessary, to alter schedules constrained by resource usage. Resource-limited scheduling also is referred to as resource-constrained scheduling.

7.2.7 Critical path/critical chain

There are many terms associated with the mechanics of project management, including node arrows, slack, and critical and non-critical paths. Critical paths and critical chains are among the most important. The critical path is the longest sequence of activities from the start to the completion of a project. The critical chain is a similar concept, but it includes resource constraints.

7.3 Project metrics

Project metrics are the final measurement and evaluation of a project. Metrics are selected, established, and set for assessment in the early phases of a project, if not immediately. Common project metrics are the duration of a project, its earliest completion time, the number of critical paths, and project slack. Budgets and financial ratios are used to analyze and assess the ongoing and final value of the project. Customer, user, and practitioner surveys also are used to measure and evaluate projects.

7.3.1 Post-project reviews

Post-project reviews evaluate how a project might have been done differently to improve outcomes. They become particularly important when similar projects are repeated over time.

CHAPTER 8

Advanced Manufacturing and Service Technology

8.1 Information technology

8.1.1 Enterprise resources planning (ERP)

ERP software helps plan and control various aspects of the extended enterprise. ERP was developed to expand the features of manufacturing resource planning (MRP II), which controlled the internal supply chain from business planning to supply chain execution.

ERP systems can include functions such as demand management, including forecasting and sales promotion; human resource management; product data management; document management; project management; business intelligence; sales planning; traditional manufacturing planning and control systems; and nontraditional pieces to facilitate lean manufacturing. ERP also can include accounting systems, maintenance systems, vertical supply chain planning (multi-plant planning), and distribution requirements planning (or their equivalents).

Quality management support is sometimes added to ERP, as well as failure mode and effects analysis, control plans, and statistical process control features. These applications all may be from a single supplier, or several different suppliers of best-of-breed solutions may be integrated. (See section 5.1.)

8.1.2 Electronic data interchange (EDI)

EDI is a way for a firm to communicate with customers and suppliers. In North America, various industry groups establish and publish standards for standard transaction sets. A common standard is by the Accredited Standards Committee X12 (ASC X12). The United Nations standard for EDI is called EDIFACT. EDIFACT is used for administration, commerce, and transportation. Electronic Business eXtensible Markup Language (ebXML) is a modular suite of specifications for conducting business over the Internet.

8.1.3 Electronic graphic interchange (EGI)

EGI is a standard for the digital representation of blueprints and other graphics.

8.1.4 Automated identification and data capture (AIDC)

Methods of automated identification are used to define and distinguish inventories by creating unique identifiers, usually in connection with data capture. AIDC is a set of technologies that collect data about objects and then transmit the data to a computer without any human intervention.

.1 Product codes

Machine-readable product codes often are affixed to a product or package to aid transactions of goods across the supply chain. Because these codes must be both understandable and unique in their uses across complex supply chains, organizations were created to assign and control product codes and their associated databases. Product codes have evolved for specialized use in areas such as health care and libraries.

Universal product code (UPC). UPC is a common product code standard in the United States. It is managed by GS1US, a successor organization to the Uniform Code Council.

European article number (EAN). EAN is a common product code in the European Union. EANs are managed by GS1, a leading global organization dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors.

Other product code standards. Other countries have their own codes, such as the Japanese article number in Japan. Such codes are collectively known as global trade item numbers and often are displayed as bar codes. (See section 8.1.4.3.)

.2 Radio frequency identification (RFID)

RFID is a wireless AIDC technology used to track and manage items. RFID uses electronic tags that contain data encoded onto an integrated circuit. A reading device sends an electromagnetic signal to the tag, which transmits its code back to the reader. There are three types of RFID tags (also called transponders): passive, active, and semi-passive.

Passive tags are not equipped with a battery. They are activated by a reader. Active tags are equipped with a battery that amplifies the signal transmitted back to the reader. Semi-passive tags, sometimes called battery-assisted passive tags, are equipped with batteries that energize built-in sensors.

.3 Bar codes

A bar code is a representation of information in a machine readable format. Bar codes are normally dark ink on a light background, creating high and low reflectance; this makes it easier for computers to read. Bar codes are widely used as part of AIDC systems for improving the speed and accuracy of data entry.

.4 Geographic information system (GIS)/global positioning system (GPS)

GIS is a system for capturing, storing, analyzing, and managing data and associated attributes spatially referenced to the planet. GIS is used for resource management, asset management, and logistics. Used in conjunction with a GPS, it can perform functions such as seeing the location of fleets to better consolidate and possibly backhaul, or the location of shipments en route.

8.2 Automated Manufacturing

8.2.1 Flexible manufacturing systems (FMS)

An FMS is a manufacturing process that can respond quickly and easily to predicted and unpredicted changes. This flexibility generally falls into one of two categories: machine and routing. Machine flexibility reflects a system's ability to change and produce new product types and its ability to change the order of operations executed on a part. Routing flexibility reflects the ability to use multiple machines to perform the same operation on a part as well as the ability to absorb large-scale changes, such as in volume, capacity, or capability.

Most are comprised of three subsystems. Work machines are often automated computer numeric control machines that are connected by a material handling system to optimize part flow. A central control computer manages material movements and machine flow. The main advantage of FMS is its high flexibility in managing manufacturing resources, such as time and effort to manufacture a new or low-volume product. FMS is best applied in small-batch and high-variety product lines.

Other advantages of FMS include fast response to changing customer needs, short preparation times for new and prototype products, low costs for low volume, the ability to handle high-variety product lines, and high productivity due to fast changeover times. High flexibility enables high machine utilization and fast detection of quality problems at lower cost.

8.2.2 Mass customization

Mass customization in marketing, manufacturing, and management is the use of flexible, computer-aided manufacturing systems, speedy information flow, and responsive processes to produce custom output. These systems combine the low unit costs of mass production processes with the flexibility of individual customization.

8.3 Advanced service systems

8.3.1 Automated service systems

Customer self-service typically is supported by automated systems. Automated systems depend on some form of input device to capture data such as sensors, bar code readers, magnetic strip readers, and voice-to-data translators. They also need a processing system, ranging anywhere from software or firmware logic systems and simple processors to super computers. A communication network connecting the input device to the processor is also required, which can be hard wired, wireless, or both. Examples of automated service systems include credit card readers, self-serve blood pressure readers, and point-of-sale systems.

Point-of-sale (POS) systems. POS systems capture information about an item at the point of sale, normally by reading bar codes or radio frequency identification codes to receive either a product code or a link to an item database. POS information drives sales transactions by retrieving item descriptions and prices. Information read in a POS system can also be linked to other information to guide special handling, retrieve materials safety data sheets, reorder materials, and account for material costs and allocations as they pass through the system.

Voice-activated service systems. Financial, insurance, and utility companies are currently leaders in using voice-activated systems to capture and translate customer data before a customer is connected with a person, who will then have the customer's service record available. The input device (in this case a voice translation) creates a query to the customer relationship system database to find the customer's data. This data then is relayed to the customer via a text-to-voice translator or by a customer service representative.

8.3.2 Remote sensing systems

Sensors can monitor the performance of production systems, capturing data such as heat and pressure in steam systems, flue gas emission in smokestacks, and rotation speeds and voltages in electric generators. Sensors can monitor flow rates in petrochemical plants, gas and water distribution networks, and heating and air conditioning systems. Remote sensing is used when direct monitoring is impractical, cost prohibitive, or unreliable.

CHAPTER 9

Emerging Operations Technologies

Emerging operations technologies change the way businesses operate. The rate of change continues to increase, creating new opportunities while simultaneously threatening existing operational methodologies.

9.1 Web collaboration/e-business

The nearly universal access to internet technology has changed the business world. The speed, simplicity, and low cost of entry into the internet marketplace impacts how businesses and individuals interact.

9.1.1 Business-to-business (B2B) commerce

B2B commerce is business conducted over the internet between businesses. Through this kind of connectivity, businesses can become tightly linked due to information sharing, enabling them to reduce costs, improve quality, reduce delivery lead time, and improve due-date performance.

9.1.2 Business-to-consumer (B2C) sales

B2C sales are transactions conducted largely over the internet between businesses and consumers. This includes traditional brick-and-mortar companies that also offer products online, as well as businesses that perform exclusively electronically.

9.2 Warehouse management systems (WMS)

WMS refers to software applications that manage the flow of materials into, through, and out of storage facilities. A typical WMS can provide detailed directions for receiving, storing, bin selecting, picking, and shipping tasks required in all warehousing operations. By shifting some of the decision making from independent human operators to a centralized planning system, measurable benefits can be achieved. These planning systems support warehouse workers through standardized processes, instructions, rules, and parameters established during system implementation.

9.2.1 Automated order picking

There are three methods of order picking: manual, semi-automated, and fully automated. Manual picking involves a human picker physically retrieving an item from a bin. Semi-automated systems bring the item to the picker. Horizontal and vertical carousels are used extensively in this approach. In automated order picking, product is picked without direct human interaction, eliminating a picker from any direct, hands-on activity.

9.2.2 Automated storage and retrieval systems

An automated storage and retrieval system is a high-density rack inventory storage system that uses vehicles to automatically load and unload the racks. It is best suited in places that machines can put away and retrieve materials and free up workers to perform other (perhaps-less dangerous) tasks. The capital costs required to purchase and maintain automated storage and retrieval systems limits their application solely to high-volume operations.

9.3 Virtual team collaboration

Virtual team collaboration can be grouped into two approaches: asynchronous and synchronous.

Asynchronous. Asynchronous collaboration occurs when two or more parties work on an activity at different times. Asynchronous collaboration techniques include document storage and retrieval, electronic voting activities, wiki repositories, email, and threaded discussions.

Synchronous. Synchronous collaboration activities occur when two or more parties share, view, or manipulate the same content at the same time. Synchronous collaboration techniques include presentation sharing, webinars, application sharing, and instant messaging.

9.4 Rapid prototyping

Rapid prototyping is the transformation of product designs into physical prototypes. Rapid prototyping relies on techniques such as cross-functional teams, data sharing, and advanced computer and communication technology—for example, computer-aided design, computer-aided manufacturing, stereolithography, and data links.

Rapid prototyping involves producing prototypes on production equipment as often as possible. It improves product development times and allows for cheaper and faster product testing, assessment of the ease and cost of assembly, and validation before actual production tooling. Rapid prototyping also includes the transformation of system designs into computer system prototypes, in which a user can experiment to determine the capability of a design to address his or her needs.

APICS OMBOK Framework
Appendices

In May 2009, APICS conducted two surveys of operations and supply chain management professionals. Respondents related the relevancy of specific *APICS Operations Management Body of Knowledge (OMBOK) Framework* topics to their work. Respondents evaluated each *APICS OMBOK Framework* topic as directly relevant, generally relevant, or not relevant to their own or their teams' responsibilities. Analysis of the data revealed which topics have greater relevancy for each job title and industry. A checked box indicates that the topic is very relevant—a frequent responsibility. Unchecked boxes indicate the topic is not relevant or is a task performed infrequently. Over the course of an operations management professional's career, he or she may encounter all topics covered in the framework.

APICS created two appendices out of the surveys for the *APICS OMBOK Framework*. The first appendix is based on the results for the non-manufacturing industries of distribution, health care services, retail, utilities, and hospitality. The second appendix is based on operations and supply chain management professionals currently in the following job titles:

- materials management director/manager
- supply chain director/manager
- distribution/logistics director/manager
- master scheduler
- buyer/planner
- demand planner
- master scheduling manager
- purchasing director/manager
- warehouse manager
- lean operations facilitator
- supply chain analyst
- capacity planner (internal and external).

Appendix I: Relevancy by Industry (Non-Manufacturing)

OMBOK SECTION	Distribution	Health Care	Retail	Utilities	Hospitality
OMBOK Chapter 2—Strategy					
2.1 Operations Strategy	X	X	X	X	X
2.2 Supply Chain Strategy	X	X	X	X	X
2.4 Operations Management Links to Other Business or Organizational Areas	X	X	X	X	X
2.5 Product/Service Design	X	X	X	X	X
2.6 Strategic Capacity	X	X	X	X	X
OMBOK Chapter 3—Supply Chain					
3.1 Responsiveness, Agility, and Efficiency	X	X	X	X	X
3.2 Supply Chain Visibility	X	X	X	X	
3.3 Risk Management	X	X	X	X	X
3.4 Locating Facilities	X	X	X	X	X
3.5 Distribution	X	X	X	X	X
3.6 Warehousing	X	X	X	X	
3.7 Logistics	X	X	X	X	
3.8 International Regulations	X				
3.9 Strategic Sourcing	X	X	X	X	X
3.10 Customer Relationship Management	X	X	X	X	X
3.11 Lean Management	X	X	X	X	X
OMBOK Chapter 4—Processes					
4.1 Process Mapping	X	X	X	X	X
4.2 Manufacturing Process Environments					
4.3 Service Processes	X	X	X	X	X
4.4 Quality	X	X	X	X	X

OMBOK SECTION	Distribution	Health Care	Retail	Utilities	Hospitality
OMBOK Chapter 5—Planning and Control					
5.1 Enterprise Resources Planning (ERP)		X		X	
5.2 Inventory: Dependent and Independent Demand	X	X	X		
5.3 Master Planning	X	X	X	X	X
5.4 Demand Management and Forecasting	X	X	X	X	X
5.5 Sales and Operations Planning (S&OP)	X	X	X	X	X
5.6 Material Requirements Planning (MRP)	X	X	X	X	X
5.7 Distribution Requirements Planning (DRP)	X	X			
5.8 Inventory Management	X	X	X	X	X
5.9 Inventory Models	X	X	X	X	
5.10 Vendor-Managed Inventory	X	X	X	X	
5.11 Collaborative Planning, Forecasting, and Replenishment (CPFR)	X	X	X		
OMBOK Chapter 6—Scheduling					
6.1 Routing	X		X		
6.2 Standards (Time Measurement)	X	X	X		X
6.3 Scheduling Techniques	X	X	X	X	X
6.4 & 6.5 Dispatching* (See OMBOK 6.5)	X				
6.6 Queuing and Simulation				X	
6.7 Theory of Constraints (TOC)				X	
6.8-6.9 Advanced Planning Systems (APS)					
6.10 Production Activity Control (PAC)	X	X	X		X
6.11 Manufacturing Execution System Management - Tracking	X			X	
OMBOK Chapter 7—Project Management					
7.1 Project Organization	X		X	X	
7.2-7.3 Planning Processes		X	X	X	

OMBOK SECTION	Distribution	Health Care	Retail	Utilities	Hospitality
OMBOK Chapter 8– Advanced Manufacturing and Service Technology					
8.1 Information Technology	X	X	X	X	X
8.2 Automated Manufacturing					
8.3 Advanced Service Systems					
OMBOK Chapter 9–Emerging Operations Technologies					
9.1-9.4 Web Collaboration/E-Business, Warehouse Management Systems (WMS), Virtual Team Collaboration Rapid Prototyping	X	X	X	X	

Appendix II: Relevancy by Job Title

	Materials Manager	SC Manager	Dist. Manager	Master Planner	Buyer/ Planner	Demand Manager	Master Scheduling Manager	Purchasing Manager	Ware-house Manager	Lean Ops Facilitator	SC Analyst	Capacity Planner
OMBOK Chapter 2—Strategy												
2.1 Operations Strategy	X	X	X	X	X	X	X	X	X	X	X	X
2.2 Supply Chain Strategy	X	X	X	X	X		X	X	X	X	X	X
2.4 Operations Management Links to Other Business or Organizational Areas	X	X	X	X	X	X	X	X	X	X	X	X
2.5 Product/Service Design		X	X	X			X	X				
2.6 Strategic Capacity	X	X	X	X	X	X	X	X		X	X	X
OMBOK Chapter 3—Supply Chain												
3.1 Responsiveness, Agility, and Efficiency	X	X	X	X	X	X	X	X	X	X	X	X
3.2 Supply Chain Visibility	X	X	X	X	X	X	X	X	X	X	X	X
3.3 Risk Management	X	X	X	X	X	X	X	X		X	X	X
3.4 Locating Facilities		X	X									
3.5 Distribution	X	X	X	X	X	X	X	X	X	X	X	X
3.6 Warehousing	X	X	X	X	X		X	X	X	X	X	
3.7 Logistics	X	X	X	X	X		X	X	X	X	X	X
3.8 International Regulations	X	X	X		X			X			X	
3.9 Strategic Sourcing	X	X	X	X	X			X			X	X
3.10 Customer Relationship Management	X	X	X	X	X	X	X	X		X	X	X
3.11 Lean Management	X	X	X	X	X		X	X	X	X	X	X
OMBOK Chapter 4—Processes												
4.1 Process Mapping	X	X	X	X	X		X	X	X	X	X	X
4.2 Manufacturing Process Environments		X		X				X		X		
4.3 Service Processes		X						X				
4.4 Quality	X	X	X	X	X		X	X		X	X	X

	Materials Manager	SC Manager	Dist. Manager	Master Planner	Buyer/ Planner	Demand Manager	Master Scheduling Manager	Purchasing Manager	Ware-house Manager	Lean Ops Facilitator	SC Analyst	Capacity Planner
OMBOK Chapter 5—Planning and Control												
5.1 Enterprise Resources Planning (ERP)	X	X	X	X	X	X	X	X	X	X	X	X
5.2 Inventory: Dependent and Independent Demand	X	X	X	X	X	X	X	X	X	X	X	X
5.3 Master Planning	X	X	X	X	X	X	X	X	X	X	X	X
5.4 Demand Management and Forecasting	X	X	X	X	X	X	X	X		X	X	X
5.5 Sales and Operations Planning (S&OP)	X	X	X	X	X	X	X	X	X	X	X	X
5.6 Material Requirements Planning (MRP)	X	X	X	X	X	X	X	X	X	X	X	X
5.7 Distribution Requirements Planning (DRP)	X	X	X	X	X	X		X	X		X	X
5.8 Inventory Management	X	X	X	X	X	X	X	X	X	X	X	X
5.9 Inventory Models	X	X	X	X	X	X	X	X	X	X	X	X
5.10 Vendor-Managed Inventory	X	X	X	X	X	X		X	X		X	X
5.11 Collaborative Planning, Forecasting, and Replenishment (CPFR)	X	X	X	X	X	X	X	X	X	X	X	X
OMBOK Chapter 6—Scheduling												
6.1 Routing	X	X	X	X	X		X				X	
6.2 Standards (Time Measurement)	X	X	X	X			X				X	X
6.3 Scheduling Techniques	X	X	X	X	X		X			X	X	X
6.4-6.5 Dispatching* (See OMBOK 6.5)	X		X	X			X				X	X
6.6 Queuing and Simulation			X	X								
6.7 Theory of Constraints (TOC)	X	X	X	X			X	X				

	Materials Manager	SC Manager	Dist. Manager	Master Planner	Buyer/ Planner	Demand Manager	Master Scheduling Manager	Purchasing Manager	Ware-house Manager	Lean Ops Facilitator	SC Analyst	Capacity Planner
6.8-6.9 Advanced Planning Systems (APS)		X	X	X		X					X	X
6.10 Production Activity Control (PAC)	X	X	X	X	X		X	X	X		X	X
6.11 Manufacturing Execution System Management - Tracking	X	X	X	X	X		X	X			X	X
OMBOK Chapter 7—Project Management												
7.1 Project Organization	X	X	X	X	X	X	X	X	X	X	X	
7.2-7.3 Planning Processes	X	X	X	X		X	X	X		X	X	
OMBOK Chapter 8—Advanced Manufacturing and Service Technology												
8.1 Information Technology	X	X	X	X	X	X	X	X	X	X	X	
8.2 Automated Manufacturing				X								
8.3 Advanced Service Systems												
OMBOK Chapter 9—Emerging Operations Technologies												
9.1-9.4 Web Collaboration/ E-Business Warehouse Management Systems (WMS) Virtual Team Collaboration Rapid Prototyping	X	X	X					X				

Index

Feedback Form

The *APICS Operations Management Body of Knowledge (OMBOK) Framework* is continually changing. APICS welcomes comments on current content and suggestions of new content to add to the *APICS OMBOK Framework*. Please use this form to provide your feedback, and send your submissions to the address at the bottom of the page.

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