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Chapter 15

Integrated Production Processes (IPP)

Learning Objectives

After reading this chapter, you should be able to:

- Appreciate the forces that exist in the contemporary production environment and the trends that have emerged.
- Understand the role of enterprise systems (ES) in the integration of the total manufacturing environment.
- Understand the key inputs, outputs, data, processes, and terminology included in modern integrated production processes (IPP).
- Understand the relationship between integrated production processes (IPP) and other key business processes within a manufacturing organization, including HR management, purchasing, order entry/sales, and inventory management.
- Understand the role of inventory management systems and their relationship to integrated production processes (IPP).

In mid-1999, the Toyota Motor Corp. shook up the automotive industry when it announced it would be able to produce a custom order auto in just 5 days. The announcement came in an industry known for taking closer to 60 days for custom orders. Even DaimlerChrysler Corp., who was perceived to have the industry lead, was averaging over twice the Toyota-announced turnaround at 12 days. Most automotive manufacturers have been working with a goal of achieving 10 days in the future—a time that falls well short of that promised in the Toyota announcement.[1] Toyota planned to achieve the newly announced custom order fulfillment promise with its "next generation just-in-time logistics system." This system is driven by a 15-day advanced plan "virtual production line," which forms the initial manufacturing plan. This plan generates the provisional orders for parts from its suppliers that can be revised up to 5 days before actual production. The process is facilitated by a complex parts delivery system that provides for parts pickups from suppliers and delivery to the plant on average 24 times a day. This

1 Even five years later, in 2004, being able to produce an automobile 10 days after a customer order, was the basis for BMW to win a manufacturing productivity achievement award. See "BMW: Custom Cars on Demand," http://www.mmh.com, 2/1/2004.

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strategy further reduces parts storage requirements by 37 percent at the plant level and reduces in-house finished goods (i.e., automobiles) inventories by 28 percent on average, helping significantly reduce inventory carrying costs. What is the impact of such strategies and systems on the bottom line of a company such as Toyota? Since 1999, Toyota has moved from being a company that was ranked a distant third in worldwide sales, to a near tie for second, and projected to be first by 2010. This growth has occurred without sacrificing profitability; Toyota is the profitability leader in the automotive world.[2]

Because integrated production systems can help companies achieve greater success, this chapter explores issues surrounding production scheduling and inventory management. We also look at the role of the accountant and business advisor in improving the efficiency and effectiveness of integrated production processes, and ultimately the profitability of the firm.

Synopsis

We begin by examining the state of competition in the international manufacturing environment and the pressures that continue to increase for organizations to reduce costs, increase the global reach of their operations across the value chain, and quickly design and deliver innovative products to meet customers' ever-increasing demands. In this context, we describe how product and process innovation, supply chain management, and management accounting systems combine with IPP to manage global complexity. Then we provide an overview of the steps in the IPP, emphasizing the role of enterprise systems and management accounting information in managing this process. We also discuss inventory management and its important role in the IPP.

Our approach in this chapter is to provide a broad overview of the IPP, focusing on how they integrate with other processes you have already discussed and their importance to achieving the strategic objectives of manufacturing businesses. We use a level 0 data flow diagram (DFD) to illustrate these processes. Entire books have been devoted to some individual topics in this chapter, so each process described may encompass quite a number of individual activities. Our aim is to provide you with an idea of the key goals of the processes, a basic understanding of how they work, and exposure to some of the key terminology involved. We do not present a system flowchart or control matrix for the IPP. Although controls are very important in IPP, especially for assuring a high level of operational effectiveness, the level of detail necessary to make these documents meaningful would be beyond the scope of our coverage here.

Competing in a Global Manufacturing Environment

If one area in particular has been most impacted by global competition, it is clearly the manufacturing sector. Manufacturing is generally the quickest route for developing countries to increase their wealth and increase the wages of their citizens. Further, business as a whole and manufacturing in particular know no national boundaries in the rapidly growing global marketplace.

For instance, several Asian countries have become major players in the automobile industry, competing heavily in the United States, Australia/New Zealand, and European

2 "The global Car Industry: Extinction of the Predator," http://www.economist.com, 9/8/2005.

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markets. Automakers (as well as manufacturers in a host of other industries) have been forced to become lean, automated, customer-focused, and efficient organizations in order to survive. Recent studies have reflected such efforts with observations of marked improvements in productivity.

Dealing with the complexity that result from mounting pressures caused by exploding globalization is key to success in the manufacturing sector. In a 2003 survey of more than 392 manufacturing executives across North America and Europe, Deloitte Touche Tohmatsu identified 3 key drivers of complexity in manufacturing operations in the new millennium:[3]

- *Pressure to reduce costs throughout the value chain:* Because of global competition and the enormous buying power of "mega-retailers" such as Wal-Mart®, many companies have been forced to move operations across their value chains throughout the globe to reduce costs. Companies surveyed expect growth in sourcing of operations, from engineering to raw material supply to manufacturing, in other countries such as China and India, with little growth in these operations domestically.
- *Pursuit of new lucrative markets and channels*: Given the cost of developing and manufacturing products, companies continually seek to enter new markets around the globe to pursue growth and economies of scale and scope. The pursuit of new, growing markets such as China also explains why these same manufacturers are sourcing more and more of their value chain operations in these countries, to better and more efficiently serve these customers.
- *The quickening pace of product innovation:* Executives surveyed reported new product innovation as the number one driver of revenue growth. Additionally, with competition and globalization come greater and greater efforts to customize products to meet local needs. Coupling this need for customization with reductions in the lifecycle for new products leads to a need to introduce more successful products more quickly than ever.

A Deloitte & Touche report describes the key characteristics of those companies that are successful at managing the pressures resulting from global complexity.[4]

- *Improved internal business processes in the areas of customers, products, and supply chains:* These efforts include increased activities related to marketing, sales, and customer service; better innovation, engineering, and research and development for products; and improved sourcing, manufacturing, and distribution for supply chains.
- *Better use of technology to increase integration within and among these three areas (customers, products, and supply chains):* Benefits from improved operations in these three areas are further leveraged by using *enterprise systems* technologies such as *customer relationship management*, as discussed in Chapter 10, to link marketing sales and service and provide information measures such as customer service and retention; *product lifecycle management* (introduced in Chapter 2 and discussed later in this chapter) to tie together the steps of product development and better manage profitability; and warehouse and transportation optimization systems to tie together suppliers, distribution, and manufacturing and develop end-to-end supply chain management strategies as discussed in Chapter 12.

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3 *The challenge of complexity in global manufacturing: Critical trends in supply chain management*, 2003, London: Deloitte & Touche.

4 *Mastering complexity in global manufacturing: Driving profits and growth through value chain synchronization*, 2003, London: Deloitte & Touche.

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TECHNOLOGY APPLICATION 15.1

MANAGING GLOBAL MANUFACTURING COMPLEXITY

Case 1: Fiorucci Foods—Old World Quality Supported by High-Tech Systems

Since the mid 1800s, Fiorucci Foods has manufactured and distributed Italian deli meats. As the company grew, management decided that while its traditional products were a key to success, the company's traditional systems were a hindrance. In addition to internal needs to track products through the production process (sometimes, nearly a year for products such as prosciutto), there are also government regulations that must be considered. After replacing fragmented information systems with a state-of-the-art ERP system that included integrated production capabilities, Fiorucci has improved order accuracy and customer satisfaction; at the same time, product cost has declined through improved inventory control and usage. In addition to the positive impact on the company's bottom line, the capability of the system to track and trace products through the manufacturing process of the company helps protect Fiorucci's reputation as a supplier of quality products throughout the world.

Case 2: GlaxoSmithKline Synchronizes Manufacturing Plants to Optimize Supply Chain Management

GlaxoSmithKline, a UK pharmaceutical company, tackled complexity through global, rather than local, optimization of its supply chain. Prior to reengineering, plants produced goods for the countries or continents where they were located. The changes resulted in a drastic reduction in the number of plants, which now serve regions of the world. Plants are focused on one of three areas—flexible plants that can ramp up quickly to make new products; plants procuring large quantities of established drugs, whose volumes are more predicable; and plants dedicated to established pharmaceuticals, especially those for small markets. This strategy, which results in single plants serving larger regions around the world, helps the company optimize supply chain activities for each type of product and overcome local supply constraints that might get in the way of quickly delivering new products. The result was savings of $500 million a year.

Case 3: Samsung Electronics Gets in Touch with Customers and Markets

Samsung, a South Korean consumer electronics company and the number one maker of big-screen TVs, has grown through better customer information gathering, which helps the company improve sales forecasts and assure orders are fulfilled on time. To gather vital qualitative and quantitative information, Samsung hires third-party ''detailers'' who visit stores, such as Best Buy and Circuit City, that stock Samsung products. These detailers monitor quality and stock levels, evaluate displays and promotions, and monitor competitor products and prices, entering data about each of these directly into Samsung's enterprise system. They also talk with customers about new product ideas at very early stages of product development. Employees from product development, sales, and marketing then use this information to make improvements to product designs, sales forecasts, and promotion strategies.

Sources: K. Hoffman, ''New Technology Helps Assure Old World Quality,'' *Supply Chain Manufacturing & Logistics*, September 26, 2005; http://www.fioruccifood.it; *Mastering Complexity in Global Manufacturing: Driving Profits and Growth through Value Chain Synchronization*, 2003, London: Deloitte & Touche.

- *Better general capabilities in the areas of collaboration, flexibility, visibility, and technology:* These capabilities, both within the company and extending out to customers and suppliers, help the best companies integrate their efforts across customer, product, and supply chain activities to focus on overall profitability. They ensure that engineers consider the flexibility of products they design, that supply chain designers consider the future need for rapid change in supply chain processes, and that customer communication lines lead to products that meet or exceed customer expectations.

Technology Application 15.1 presents three case studies illustrating how companies have demonstrated these characteristics to increase overall profitability.

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Deloitte's research shows that globalization and efforts to manage it pay off. The 7 percent of survey respondents with both high *value chain* capabilities and high global dispersion of sourcing, manufacturing, engineering, and marketing/sales operations across their value chains were 73 percent more profitable than their counterparts with low value chain capabilities and global dispersion.

In the following sections, we further explore several of the trends in global manufacturing companies that help them achieve the level of integration described previously. In particular, we examine the following four key components of effective, integrated production processes in more depth:

1. Product innovation
2. Production process innovation
3. Supply chain management
4. Management accounting systems

Product Innovation

Designing innovative products and getting them to market quickly is key to competition in the complex global manufacturing environment. To accomplish rapid product innovation, cooperation among engineering, manufacturing, and marketing is vital. Production conventionally has been organized along functional lines. Under the functional approach to developing a product, the process is undertaken as a series of discrete, independent steps, such as design, engineering, purchasing, manufacturing, and so forth. The schism that results between the "me think" design component and the "you do" manufacturing element has been extremely inefficient both in terms of getting products to market on time and controlling production costs.

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Enterprise systems facilitate the integration of all aspects of the product design, manufacturing, and marketing processes. Dramatic productivity gains have been achieved by companies that adopt a *value chain* approach that views production as a continuum, beginning with product design and running all the way through materials acquisition, manufacturing, distribution, marketing, and servicing of the product in the field. For example, with a value chain approach and effective use of enterprise systems, when changes are made to product design (engineering change orders), the change is automatically messaged to the production facilities, and the change is incorporated in real-time. Japanese manufacturers have been particularly successful in improving product quality by fostering a close cooperation between the functions of design and manufacturing. Design engineers and manufacturing engineers coordinate their efforts to design a defect-free product. The result has been a streamlined manufacturing process that eliminates (or drastically reduces) the need to inspect the product.

More recently, companies have worked to implement *product lifecycle management (PLM)* systems, which are *ERP* modules or *enterprise systems* add-ons that organize data by product, including designs, manufacturing specifications, quality, and warranty performance. These systems allow collaborative access to this data across the organization by key suppliers and customers, and increase innovation in product design, reduce design time, and improve product performance.

Production Process Innovation

A major contribution of Japanese manufacturers has been their managing of *throughput time*. **Throughput time** is the time it takes from when authorization is made for goods to be produced to when the goods are completed. Japanese companies have accomplished much in this area, mainly by switching from *push* to *pull* manufacturing. With

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push manufacturing, the sales forecast drives the production plan, and goods are produced in large batches. Each machine performs its operation on the batch, and then the entire job waits until the operation can be started on the next machine in the sequence.

Conversely, with **pull manufacturing**, production is initiated as individual sales orders are received. Theoretically, each job consists of a "batch" of one unit. In pacing production, an idle machine pulls the next part from the previous machine as soon as that part is available thus pulling goods through the factory only when needed to satisfy demand. As soon as machine A completes its operation on unit 1, machine B starts work on that unit, and machine A begins on unit 2.

Adopting the pull approach has several natural concomitants:

- *Short production runs:* Rather than producing for stock, production runs reflect the size of orders received.
- *Continuous flow operations:* To approach the "ideal" batch size of one unit, plant layouts are reorganized so that goods can proceed in a continuous flow from one operation to the next.
- *Cellular manufacturing:* The modified plant layouts have led to a "cellular" arrangement of machines. In the traditional factory layout, machines are organized by departments, each containing similar types of machines. With **cellular manufacturing**, on the other hand, machines are organized in clusters or "cells" that contain all of the needed resources (machines, tools, labor) to produce a family of products. A natural extension of the cellular physical layout is a management orientation that takes a global view of overall work cell throughput rather than a narrower focus related to productivity of individual machines. In fact, it is not uncommon for a single worker to run several machines in a cell or for workers to be at least trained to operate multiple machines.
- *Reduced work-in-process and finished goods inventories:* By reducing production runs, fewer resources are in process at any point in time, reducing work-in-process inventory. In a pure pull environment, finished goods inventory will include only items that await shipment.
- *Reduced floor space:* This economy is a result of improved plant layout and elimination of space needed for inventory storage.

Supply Chain Management

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Chapter 12 defines *supply chain management (SCM)* as the combination of processes and procedures used to ensure the delivery of goods and services to customers at the lowest cost while providing the highest value to customers. Figure 12.2 in Chapter 12 (pg. 423) provided an overview of the many internal and external linkages that make up a modern supply chain and described these in the context of a merchandising organization. As evidenced by the prominence of supply chain management in our earlier discussion of the challenges facing manufacturers in an age of global complexity, the challenges of supply chain management discussed in Chapter 12 are further magnified in a manufacturing setting. Rather than being concerned with forecasting demand, lead times, and reorder points for finished goods, a manufacturer must forecast demand, determine lead times, monitor inventory levels for numerous raw materials, *and* plan for the manufacture of finished goods. Additionally, the time and resources necessary to manufacture key **subassemblies**, separately manufactured components used in the final product, must be considered. These subassemblies may be manufactured in the same plant as the final product, or they may be manufactured in a separate plant across the globe.

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E-business plays an increasing role in this process. Increasingly, suppliers are gaining access to the organization's production planning schedules to set their own production schedules and to assure the capability to fulfill orders. Similarly, the organization is opening its systems to the customer to allow the customer to view inventory and production levels before placing orders. To accomplish this in a cost-effective manner, Internet technologies are being linked to organizations' *ERP* and *supply chain management software* to provide *portals* to external organizations for safe and secure access to critical business information. In short, the simplicity of the Internet is enabling the continual growth in complexity of business processes and the underlying organizational information systems.

Of particular interest is the enhanced capability that supply chain management software provides for *available to promise* and *capable to promise* planning. **Available to promise planning** is the accumulation of the data on current inventories, sales commitments, and planned production to determine whether the production of finished goods will be sufficient to commit to additional sales orders. **Capable to promise planning** is the accumulation of the data on current inventories, sales commitments, planned production and excess production capacity, or other planned production capacity that could be quickly converted to production of the desired finished goods necessary to fulfill a sales order request. The former addresses the planned production capacity that can be used to fulfill *additional* customer orders. The latter addresses the capability to divert production capacity from other production facilities that have not been previously planned for use on producing the product needed for an incoming customer order.

Management Accounting Systems

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In this section, we will alert you to some changes that have already occurred (or are evolving) in cost management and cost accounting. Many of these changes have their origins in the developments that have transpired in the production arena and that were discussed—or alluded to—in the preceding sections. In addition, many of these changes are a result of the capability of *enterprise systems* to capture sales, product design, and production data in real-time and to share this data across the *value chain*. Table 15.1 (pg. 544) summarizes several key accounting changes as related to parallel changes in production processes.

Take some time to study Table 15.1. As do certain other parts of the chapter, the table assumes that you have a background in managerial/cost accounting. Probably the most important theme in Table 15.1 is the importance of increasing the accuracy and timeliness of cost information and the use of this information for the strategic management of products and processes throughout the value chain from design to manufacturing to marketing and post-sales servicing.

Activity-based costing is prevalent in companies seeking to increase cost accuracy and usefulness. **Activity-based costing** is a costing approach where detailed costs to perform activities throughout the value chain are computed and can be managed or assigned to cost objects, including products. Activity-based costing recognizes that *cost drivers* (measures of the amount of activity performed) other than production volume or direct labor explain many activity costs. Cost per unit of the cost driver is computed for each activity. Costs are then assigned to products based on the amount of the cost driver used. An example of an activity that might be performed for a production facility is purchasing materials; and the cost driver might be the number of purchase orders prepared.

By using a variety of cost drivers, activity-based costs can be computed for all activities across the value chain, not just manufacturing activities. Detailed activity cost information and increasingly accurate and comprehensive product costs can be used to aid strategic decisions throughout the value chain. Information about cost drivers and activity costs can be used to improve product designs and production processes, to

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TABLE 15.1 Summary of Trends in Cost Management/Cost Accounting

Development in the Production Process Environment	Related[a] Trend in Cost Management/Accounting
Shorter product lifecycles that require cost recovery over a shorter period	Emphasis on product lifecycle costing
	Shift from after-the-fact cost control reporting to reporting designed to assist strategic planning and decision making
	Increased emphasis on managing costs versus merely accounting for costs
	Attack waste as opposed to mere reporting of variances
Flexible manufacturing systems	Flexible cost systems that are also responsive to change
Factory automation	Shift in cost structure from variable costs to fixed costs
	Reduction in the direct labor cost component and in the use of direct labor for applying overhead[b]
	Increase in the overhead component of total cost[c]
	Use of a fourth cost category, direct technology, in addition to the traditional direct materials, direct labor, and overhead categories
	Use of activity-based costing (ABC) systems
Automating the information system	Real-time data capture on the factory floor
	Shift away from standard cost systems back to actual cost systems
	Reduction in the administrative costs of gathering data
	Automated inventory orders via EDI without human interaction
	Collecting statistical data in addition to financial data
Cellular organization of the factory	Elimination of *detail* reporting by shop order and by operation; instead, use of accounting for cell throughput time
	Use of cell throughput time instead of direct labor to apply overhead
	Trend toward process cost systems and away from job order cost systems
Reduced work-in-process and finished goods inventories	For internal purposes at least, abandonment of full-absorption costing, which loses its significance in the absence of inventories
	Accumulation of costs for decision making instead of for valuing inventories

[a] For simplicity, each cost trend has been listed only once. You should recognize that the items in the right column might very well relate to more than one development in the left column.
[b] For instance, in some high-tech companies, direct labor could account for as little as 5 percent of total cost.
[c] For some companies, manufacturing overhead may be as much as 70 percent of total cost.

determine the best mix of marketing campaigns or to assess the cost of poor quality. Using activity-based costing information, product managers can estimate **lifecycle costs**, or the sum of the costs to design, produce, market, deliver, and support a product throughout the product's lifecycle from conception to ultimate discontinuance, more effectively by managing product profitability.

Many of the other changes identified in Table 15.1 are also aimed at more accurate identification of costs in a timely manner so that this information can be used more strategically. Many of the changes also stem from the importance of technology in the production process. For example, the use of a new cost category, direct technology, allows these costs, which are becoming a larger component of manufacturing costs, to be

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directly estimated and more effectively managed. A separate cost category for these items is possible because of *cellular manufacturing*, which devotes machines exclusively to single product lines.

Integrated Production Processes (IPP)

Within the backdrop of the globally complex manufacturing organization, our primary purposes in this section are to (1) acquaint you with the principal components of a modern integrated production process (IPP) and the interactions that can exist among those components and to (2) arm you with basic definitions of manufacturing terms that you may encounter in your professional careers.

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Figure 15.1 (pg. 546) provides a level 0 DFD of an IPP. Consistent with the goal of integration across functional areas, the process actually begins at the start of the *value chain* with the design of the product and production processes (step 1.0). Based on data developed at this stage as well as information about expected or actual sales orders from the order entry/sales process and inventory levels from the inventory management process, a master production schedule is developed (step 2.0), followed by a detailed definition of needs for materials (step 3.0) and detailed production instructions (step 4.0). These steps initiate activities in the purchasing and HR management processes to put materials and labor resources in place to complete production. Throughout these steps, and especially as resources are used to manufacture the goods, information about the process is continuously captured (step 5.0) so that valuable managerial information can be generated. As you can see from the number of integration points with other business processes in Figure 15.1, *enterprise systems* will play a vital part in managing the IPP. Each of these steps will be discussed in more detail in the following sections.

In practice, one key to understanding the information processes described in Figure 15.1 is understanding the underlying terminology and recognizing the acronyms used to describe the processes by engineers, manufacturing managers, and software developers. Table 15.2 (pg. 547) lists each of the steps in the process and provides a summary of the common manufacturing terminology used at each step, which also will be discussed in the following sections.

Design Product and Production Processes

(Figure 15.1, pg. 546, bubble 1.0) Consistent with the value chain concept, the IPP begins with the design of the product and production processes. With approximately 80 percent of the future cost of producing the product locked in with decisions made during design, this step is vital to determining the profitability of new product lines. *Activity-based costing*, which provides information about the cost of production activities for existing products, can be used to develop estimates of the future cost of producing new products as well as potential cost changes from product and production process design changes.

The entire design process is automated through the use of **computer-aided design (CAD) and computer-aided engineering (CAE)**. Because of their close relationships to each other, it is not uncommon to talk about CAD/CAE as a single element. CAD/CAE is an application of computer technology that automates the product design process, including but not limited to the functions of geometric modeling, materials stress and strain analysis, drafting, storing product specifications, and mechanical simulation of a product's performance. The objectives of CAD/CAE are to:

- Improve design productivity
- Reduce design lead time

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FIGURE 15.1 Level 0 DFD of the IPP

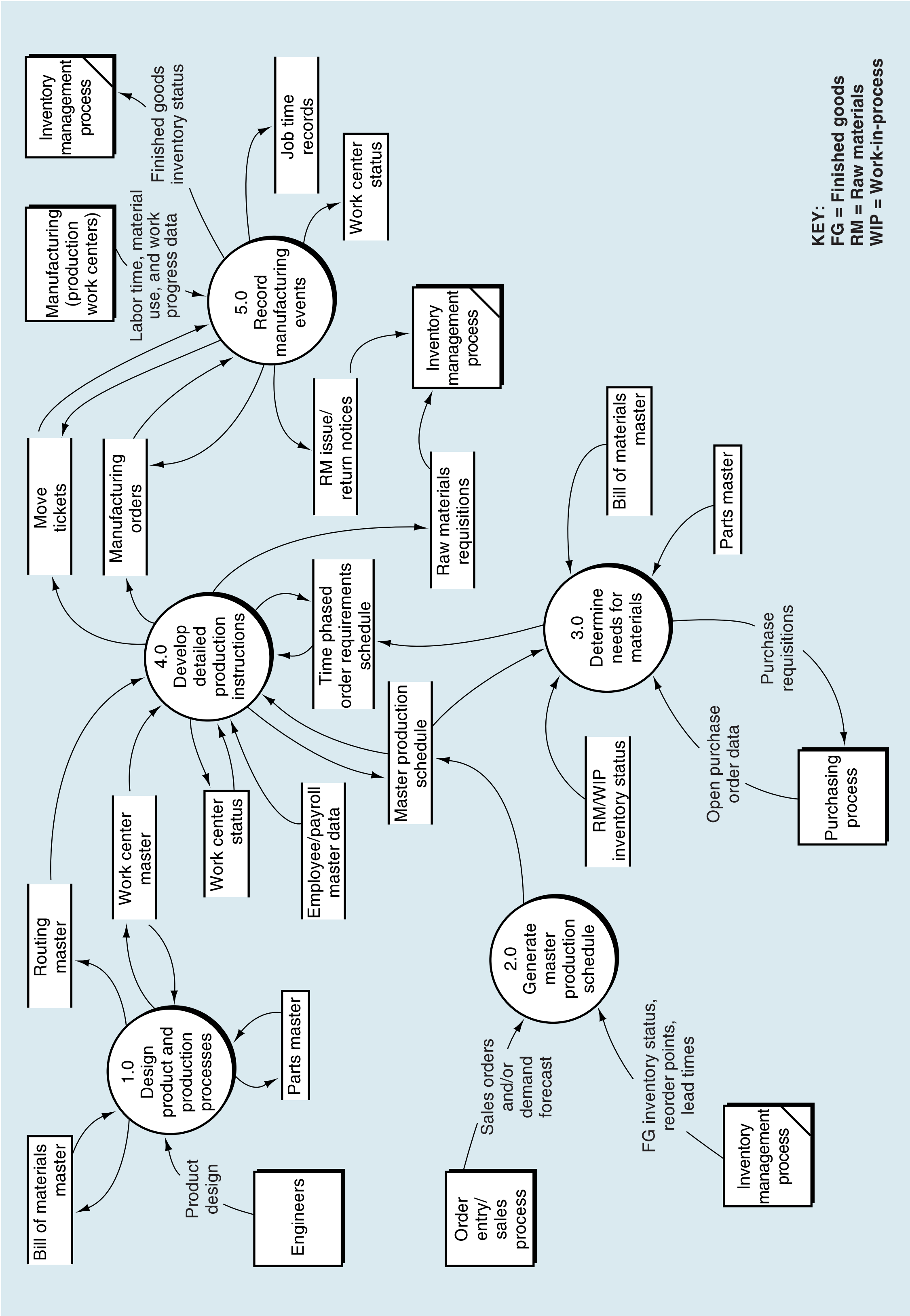

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TABLE 15.2 Key Manufacturing Terminology in the IPP Steps

IPP Step	Related Manufacturing Terminology
Step 1.0: Design product and production processes	*Computer-aided design/Computer-aided engineering* (CAD/CAE) is used to automate product design.
	Computer-aided process planning (CAPP) is used to generate manufacturing instructions and routings based on product requirements.
Step 2.0: Generate master production schedule	*Global inventory management* assures that production schedules consider inventory availability across the global enterprise.
	Production, planning, and control is the process of generating a schedule, determining detailed material needs, developing detailed production instructions, and tracking data during production.
Step 3.0: Determine needs for materials	*Materials requirements planning (little mrp)* is used to develop a time-phased requirements schedule for materials and subassemblies.
Step 4.0: Develop detailed production instructions	*Capacity requirements planning (CRP)* is used to develop detailed machine- and labor-use schedules that consider available capacity.
	Manufacturing resource planning (MRP) incorporates mrp, CRP, and planning for labor and financial capital.
External entity: Manufacturing (production work centers)	*Flexible manufacturing systems (FMS)* are automated systems used to control production that can quickly incorporate automated engineering design changes.
	Computer-aided manufacturing (CAM) is used to link machines, monitor production, and provide automatic feedback to control operations.
	Automated storage and retrieval systems (AS/RS) store and retrieve parts and tools.
	Automated guided vehicle systems (AGVS) deliver parts and tools among multiple work centers.
Step 5.0: Record manufacturing events	*Shop floor control (SFC)* is used to monitor and record the status of manufacturing orders and work centers during the manufacturing process.

- Enhance design quality
- Facilitate access to and storage of product designs
- Make the design of multiple products more efficient by eliminating redundant design effort
- Execute design changes almost immediately through the use of electronic messaging to notify the shop floor

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With the use of *enterprise systems*, the electronic designs produced using CAD/CAE become the basis for developing detailed production schedules (step 2.0) as well as the electronic control of production machines. In addition to the detailed product design, the CAD/CAE process results in several data stores of information that are used later in the IPP:

- **Bill of materials**: The bill of materials is a listing of all the *subassemblies*, parts, and raw materials that go into a parent assembly showing the quantity of each that is required to make an assembly. Often, engineers will work to design several products with common *subassemblies*. This way, manufacturing processes are more standardized, quality can be improved, and costs are reduced. The bill of materials provides the basis for later orders of raw materials (bubble 3.0) when a finished good is to be produced.
- **Parts master**: The parts master or raw material (RM) inventory master lists the detailed specifications for each raw materials item. An engineer must specify the

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information for a new record in the parts master when a new part is used in a product design. Often, existing parts will be used in new products to reduce needed ordering and carrying costs for the inventory.

- **Routing master**: The routing master specifies the operations necessary to complete a subassembly or finished good and the sequence of these operations. The routing master also includes the machining tolerances; the tools, jigs, and fixtures required; and the time allowance for each operation. The routing master is vital when developing detailed production instructions (step 4.0). **Computer-aided process planning (CAPP)** is often used in developing the routing master for new products. CAPP is an automated decision support system that generates manufacturing operations instructions and routings based on information about machining requirements and machine capabilities.
- **Work center master**: The work center master describes each *work center* available for producing products, including information such as the machine available at the station, its capacity, its maintenance needs, labor needs to operate it, and so on. A **workstation** is the assigned location where a worker performs his or her job; it could be a machine or a workbench. A group of similar workstations constitutes a **work center**. When new products require new machines or production activities, a new record in the work center master must be created.

Generate Master Production Schedule

(*Figure 15.1*, *pg. 546*, *bubble 2.0*) With products and production processes in place, the next step in the IPP is generating a *master production schedule (MPS)* to drive the production process. The **master production schedule (MPS)** is a statement of *specific* production goals developed from forecasts of demand, actual sales orders, and/or inventory information. It describes the specific items to be manufactured, the quantities to be produced, and the production timetable. Depending on the company's approach, the schedule may be based on information about finished goods inventory levels and reorder points, sales forecasts, or actual sales orders coupled with inventory levels. Based on the master production schedule, more detailed schedules for ordering raw materials and scheduling work center operations are developed in steps 3.0 and 4.0. Figure 15.2 depicts a master production schedule, including the specific items to be manufactured, the quantities to be produced, and the production timetable.

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Given the increased emphasis on cost reduction for successful global competition in manufacturing, companies cannot afford to generate too much of the wrong products. Instead, extensive use of *enterprise systems* to gather and analyze data from past and future sales and inventory levels is used to develop a more accurate production plan. The result minimizes unnecessary inventory investment and maximizes the likelihood that the right products will be in place at the right time.

The master production schedule is based on information from multiple sources. A primary source is actual orders from customers. Ideally, a manufacturer can cut *throughput time* to the point that it can produce goods only as customer orders are received. In this way, the manufacturer minimizes the risk of goods not selling and maximizes the likelihood that it will produce exactly the product desired by the customer.

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Often, however, the time necessary to produce goods and distribute them to locations around the globe necessitates producing goods in anticipation of sales orders. In this case, a variety of techniques may be used to develop sophisticated demand forecasting models that help manufacturers estimate the need for goods. These techniques can use the full complement of customer data available in the *enterprise system* about past sales levels and buying patterns to improve forecast accuracy. These models may take advantage of

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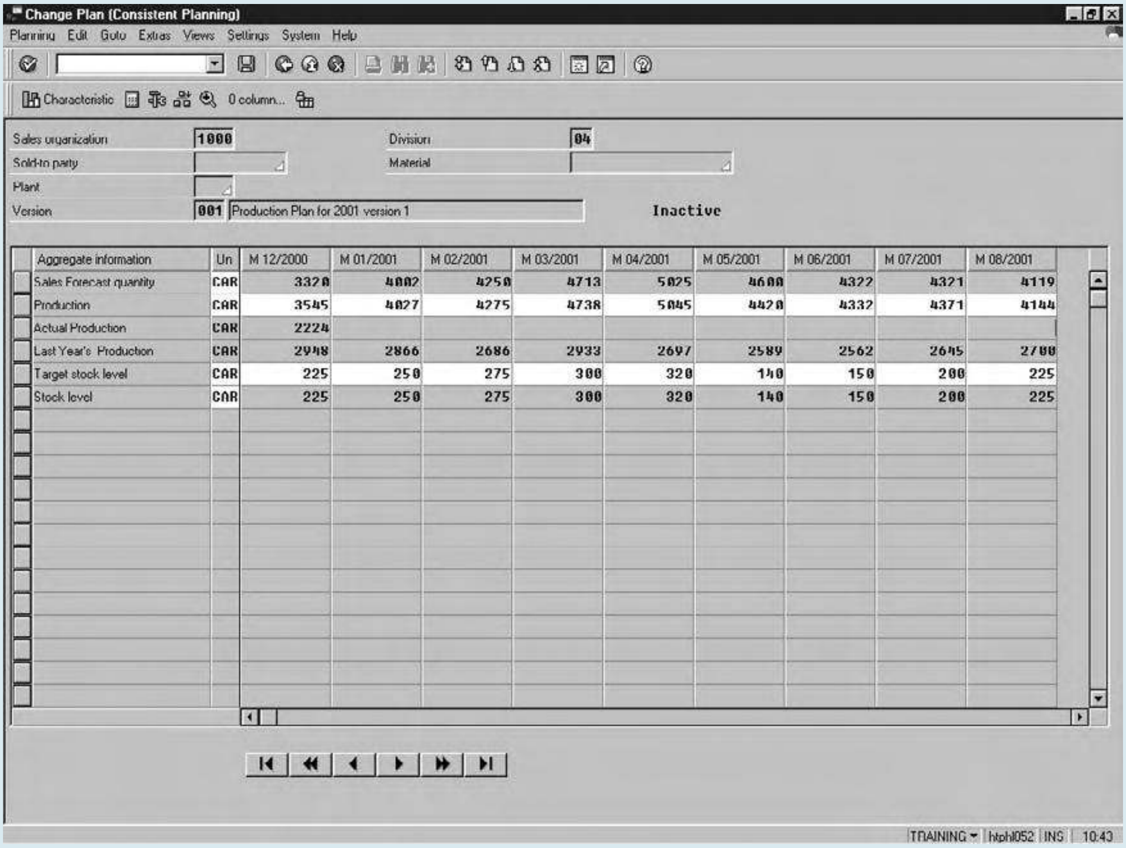
FIGURE 15.2 Dynamic Production Schedule (SAP®)



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information from the *customer relationship management* system as discussed in Chapter 10 and will likely use some of the *data mining* techniques also described in Chapter 10 to identify important patterns and relationships in the level of demand.

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Finally, the inventory management system also provides vital inputs to developing a better master production schedule. The inventory management system provides data about levels of finished goods (FG) inventory currently on hand and also gathers data about goods scheduled to be produced. Additionally, inventory data tracked over time by the company's *enterprise system*, such as lead times, optimal inventory levels, frequency of stockouts, and expected quality levels, all help develop better production schedules.

ENTERPRISE SYSTEMS

One trend in inventory management facilitated by *enterprise systems* has been particularly useful in reducing inventory levels and better satisfying customer demand. This trend is *global inventory management*. In the **global inventory management** approach, inventory needs and production capabilities are matched across the entire global enterprise, not just at a regional level. Less sophisticated inventory management systems associate specific inventory locations and manufacturing plants with specific sales regions. In this way, the South American sales region of a large electronics manufacturer would look primarily at manufacturing plants and warehouses within this same geographic region when examining the availability of inventory or production capacity to fill a large order. If insufficient capacity was available in this region, the order might be

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rejected, or a delivery date too far in the future might be quoted, resulting in losing the business to a competitor.

With *global inventory management*, the South American sales region can examine inventory and production capacity across the entire company's global organization when determining its capability to fill an order. Of course, if the product was to be produced in a factory across the globe in Germany, for example, the South American sales division would need to consider additional lead time to transport the goods to the customer and also the associated distribution costs, but these pieces of information would be readily available from the *enterprise database*.

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Armed with information from the *enterprise system* about the sales forecast, actual sales orders, and inventory data, the *master production schedule* can be developed, as depicted in Figure 15.1, bubble 2.0. Developing the MPS along with the remaining steps in the IPP are often referred to as the production, planning, and control process. *Production, planning, and control* involves the *logistics*, or "physical" aspects of converting raw materials into finished goods. As such, the **production, planning, and control** process manages the orderly and timely movement of goods through the production process. It includes activities such as planning material, people, and machine requirements; scheduling; routing; and monitoring the progress of goods through the factory.

Determine Needs for Materials

ENTERPRISE SYSTEMS

(*Figure 15.1, pg. 546, bubble 3.0*) After the master production schedule is determined, an important step in completing production in a timely manner is identifying, ordering, and receiving materials. At the heart of this task is the *materials requirements planning (little mrp)* process. **Materials requirements planning** is a process that uses bills of material, raw material and work-in-process (RM/WIP) inventory status data, open order data, and the master production schedule to calculate a **time-phased order requirements schedule** for materials and subassemblies. The schedule shows the time period when a *manufacturing order* or purchase order should be released so that the subassemblies and raw materials will be available when needed. The process involves working backward from the date production is to begin to determine the timing for manufacturing subassemblies and then moving back further to determine the date that orders for materials must be issued into the purchasing process. In an *enterprise system*, this process is performed automatically using a variety of data from the enterprise database, including the following:

- *Bills of materials (BOM)* showing the items and quantities required as developed by engineering.
- *Parts master* data, which contains information about part number, description, unit of measure, where used, order policy, lead time, and safety stock.
- *Raw materials (RM) and work-in-process inventory status* data showing the current quantities on hand and quantities already reserved for production for the materials and subassemblies.
- *Open purchase order (PO)* data showing the existing orders for materials.

The process begins by **exploding the BOM** (shown in Figure 15.3), which involves extending a bill of material to determine the total of each component required to manufacture a given quantity of an upper-level assembly or subassembly specified in the MPS. Based on lead-time data for producing and ordering, materials and subassembly requirements are output in a *time-phased order requirements schedule*, which is illustrated in Figure 15.4. Based on this schedule and open PO data, purchase requisitions are generated and sent to purchasing.

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FIGURE 15.3 Bill of Materials (Microsoft® Dynamics™ GP)

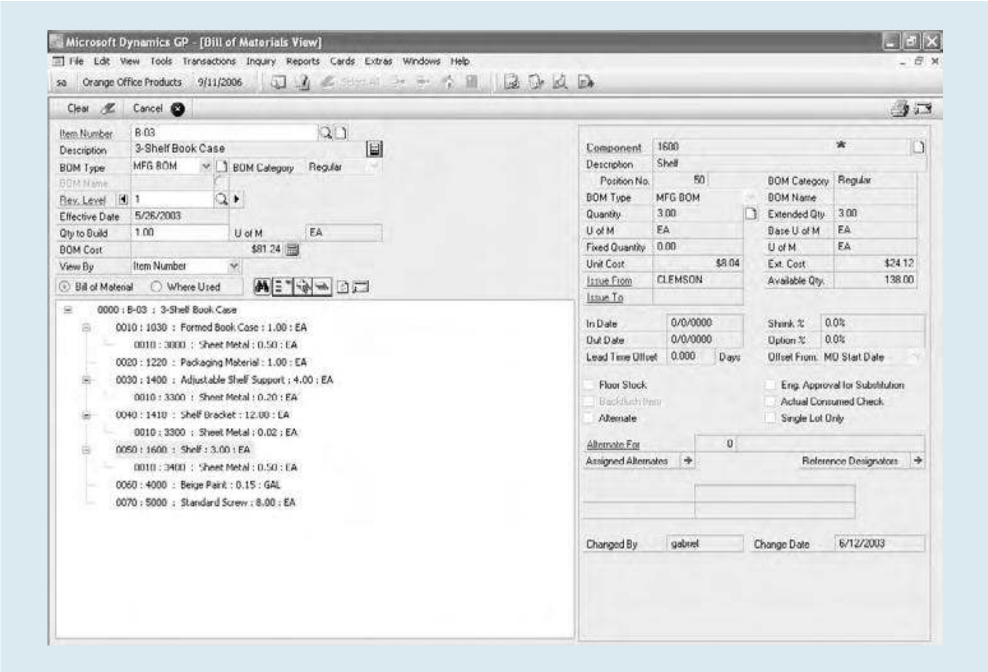

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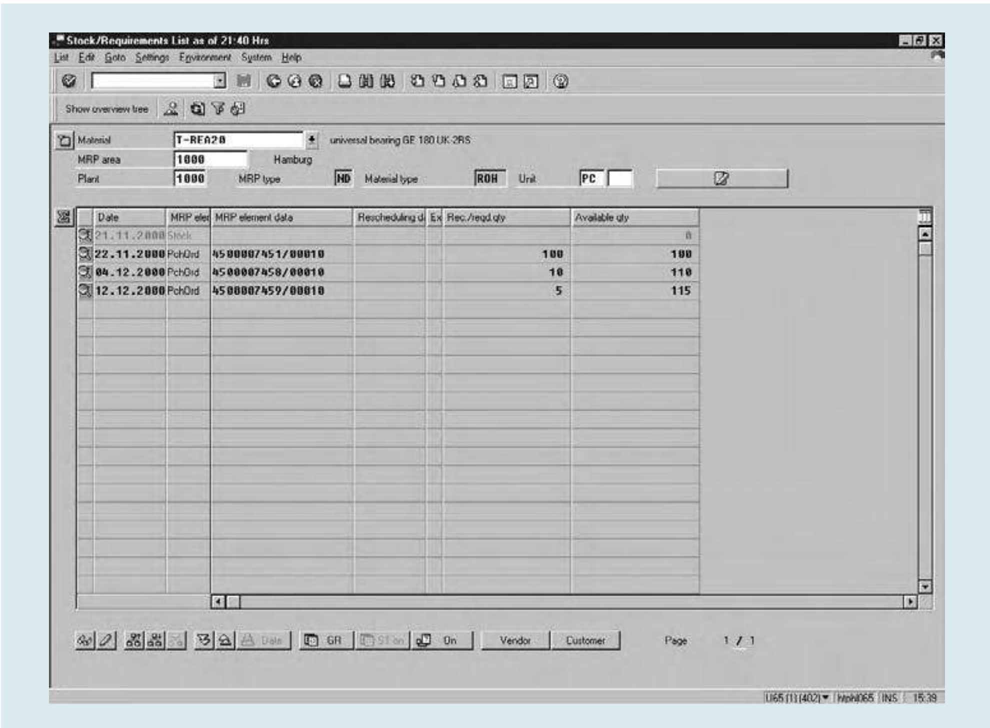
FIGURE 15.4 Order Requirements Schedule (SAP®)



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To illustrate the "explosion" of a BOM, suppose that the BOM for one mousetrap reflects the following:

Part No.	Description	Quantity
100	Wood base (36 in.)	1
101	Coil spring	2
102	Wood screw (5/8 in.)	2
103	U-shaped wire rod (24 in.)	1
104	Cheese holder and hook	1

Assume that the MPS calls for making 500 mousetraps in the week ended October 4, 20XX. Exploding the BOM would result in the following materials requirements:

Part No.	Quantity	Calculation (end units times quantity per)
100	500	(500 x 1)
101	1,000	(500 x 2)
102	1,000	(500 x 2)
103	500	(500 x 1)
104	500	(500 x 1)

Allowing for the lead time needed to have the parts available during the week of October 4, orders would be released for 500 units of parts 100, 103, and 104, and 1,000 units of parts 101 and 102, assuming open orders were not already in process for these materials.

E-BUSINESS

E-business and supply chain management may have a significant influence on the *mrp* process. With greater integration between manufacturer and vendor systems, actual orders for raw materials may be triggered by vendor systems that monitor master production schedule information and automatically ship orders at the appropriate time (i.e., *vendor managed inventory*, *VMI*). Even if this level of integration is not quite achieved, electronic transmission of orders may greatly reduce the necessary lead time for placing orders for raw materials.

Develop Detailed Production Instructions

(*Figure 15.1, pg. 546, bubble 4.0*) Materials are not the only resources necessary for beginning production. Detailed instructions showing exactly when the goods will be processed through each necessary work center and the labor necessary to complete the work are the result of step 4.0 of the IPP. In particular, consideration of the capacity available of these resources may have a profound impact on whether the organization can ultimately achieve the master production schedule. The **capacity requirements planning (CRP)** process uses the information from the *master production schedule* and *time-phased order requirements schedule* to develop *detailed* machine- and labor-utilization schedules that consider the feasibility of production schedules based on available capacity in the work center status records. Ultimately, this process may lead to modifications to the *master production schedule* or *time-phased inventory requirements schedule* if sufficient capacity does not exist to complete these schedules as planned. After these

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adjustments are completed, CRP assigns targeted start/completion dates to operations (*workstations*) or groups of operations (*work centers*) and releases manufacturing orders and move tickets to the factory.

Manufacturing orders (MOs) convey authority for the manufacture of a specified product or subassembly in a specified quantity and describe the material, labor, and machine requirements for the job. The manufacturing order is the official trigger to begin manufacturing operations. When MOs are released, they are generally accompanied by **move tickets** (usually in the form of bar code tags) that authorize and record movement of a job from one work center to another. The move ticket contains various information for tracing work completion, such as the shop work authorization number representing the job being completed; the department, machine, operator, and time of completion; and check boxes for completion of current task and inspection of prior tasks' completion. Generally, these data are captured by scanning the bar code to expedite data entry and improve accuracy.

Additionally, *raw materials requisitions* are sent to the inventory process. A **raw materials requisition** is an authorization that identifies the type and quantity of materials to be withdrawn from the storeroom and tracks the manufacturing order being produced and the work center needing the raw materials.

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Triggered by the *time-phased order requirements*, CRP used the following additional inputs from the *enterprise system* to accomplish its functions:

- The *routing master* shows the necessary steps and time to complete each operation to produce the product. Whereas the *BOM* shows the raw material inputs required for a single unit of finished goods output, the *routing master*, illustrated in Figure 15.5, (pg. 554) performs a similar function in respect to labor and machine requirements. The *routing master* typically shows the sequence of operations to manufacture an end item and the standard time allowance (labor hours or machine hours) for each operation. Based on the production orders, the total standard (required) labor and machine hours can be predicted by reference to the routing master. The calculations are similar to those used to explode a BOM.
- Resource capacity information (i.e., hours available each day/week by work center) from the *work center master data*.
- Data about the current status of work center loads from the *work center status data* (also known as *loading data*). These data can include MOs now at each work center, anticipated MOs, backlogs, and actual hours ahead or behind schedule. This data is supplemented by information from the *employee/payroll master data* that shows available labor capacities.

Together, mrp, CRP, and the process of planning cash flows to accommodate needs generated by the production schedule are referred to as **manufacturing resource planning (MRP)**. MRP is an integrated decision support system for planning, executing, and controlling manufacturing operations. It includes facilities for planning all manufacturing resources, including material, machines, labor, and financial capital.

Manufacturing (Production Work Centers)

The next information process shown in the DFD (Figure 15.1, pg. 546) is recording information about the manufacture of goods (step 5.0). However, before discussing the recording process and to help you understand the process, it is important for you to have some information about how the IPP accomplishes the manufacturing steps from which the data are recorded. First, we describe automating the production process, and then, we discuss the just-in-time aspects of manufacturing.

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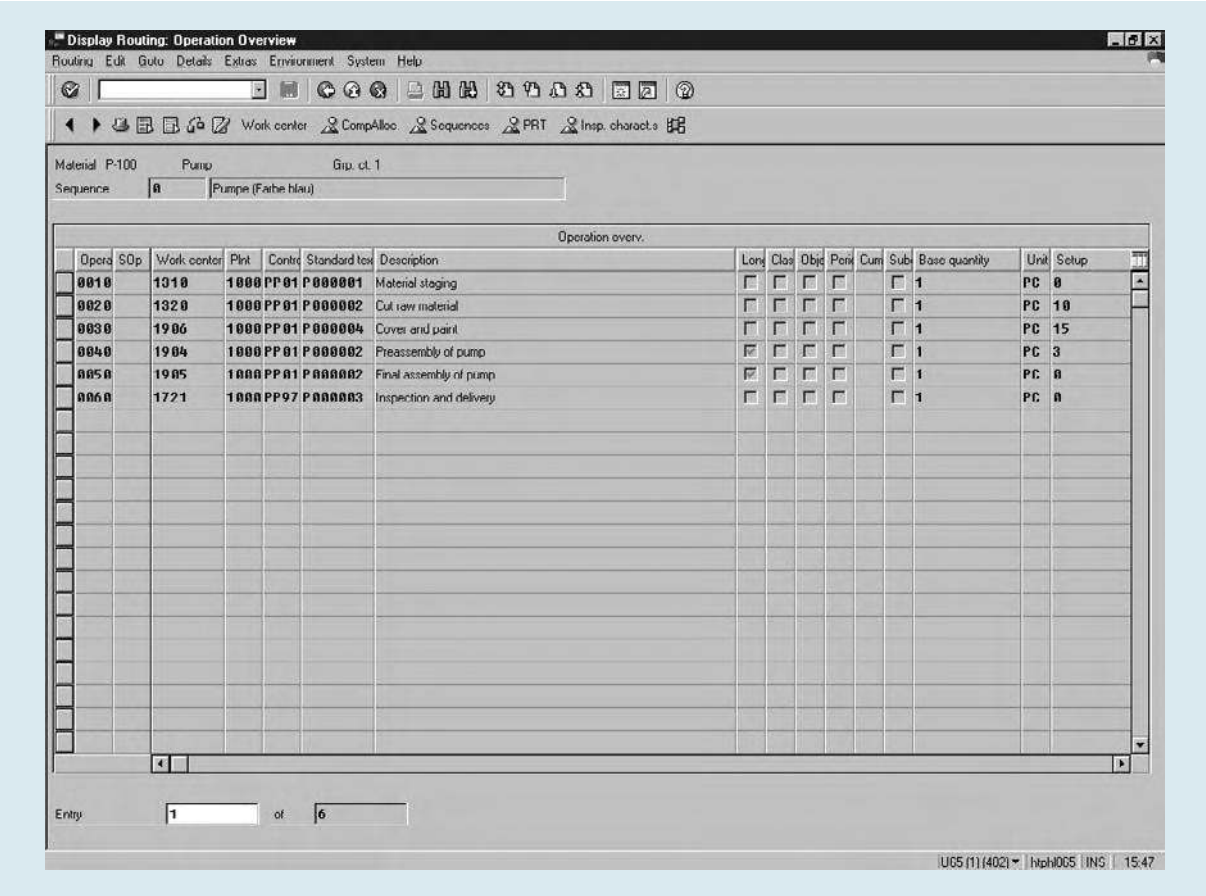
FIGURE 15.5 Production Routing Schedule (SAP®)



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Manufacturing Automation

Flexible manufacturing systems (FMS) are used to control the actual production of the goods. An *FMS* is an automated manufacturing operations system that can react quickly to product and design changes because a centralized computer control provides real-time routing, load balancing, and production scheduling logic. Regardless of its components, any FMS has as its goal making the plant more flexible—that is, achieving the capability to quickly produce wide varieties of products using the same equipment.

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A component of FMS, **computer-aided manufacturing (CAM)**, is the application of computer and communications technology to improve productivity by linking computer numerical control (CNC) machines, monitoring production, and providing automatic feedback to control operations. CAM is intended to improve manufacturing control and reporting, coordinate material flow between machines, and facilitate rerouting. CAM systems take advantage of integration within *enterprise systems* to automatically incorporate design changes made by engineering into production processes on a nearly real-time basis, thereby decreasing the time to integrate new innovations.

Central to the *actual work performed* in an FMS environment is the use of machines that use *computer numerical control (CNC)*. These machines might be industrial robots or automated materials handling systems in the form of **automated storage and retrieval**

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systems (AS/RS), which are computer-controlled machines that store and retrieve parts and tools, or **automated guided vehicle systems (AGVS)**, which are computer-based carts that are capable of delivering parts and tools among multiple work centers. Regardless of the type, numerically controlled machines, in general, represent one of the earliest efforts at factory automation and have evolved in an attempt to improve worker productivity, enhance product quality and precision, and avoid the risk posed to humans by hazardous working conditions. Differences among numerically controlled machines lie mainly in the degree of process knowledge (i.e., how to operate the machine) that is transferred from the laborer to the machine (i.e., by being programmed into the machine). In some settings, a worker is still needed to load, unload, and set up the machine. Robotics and industrial parts inspection done by digital image processing machines virtually eliminate the worker and achieve productivity that is technology-paced only.

Just-In-Time Manufacturing

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Many manufacturers have simplified their manufacturing operations and reduced inventories through the use of a **just-in-time (JIT)** approach to controlling activities on the shop floor. Just-in-time is a *pull* manufacturing philosophy or business strategy for designing production processes that are more responsive to precisely timed customer delivery requirements. Several inherent JIT objectives and the means of attaining them are summarized in Exhibits 15.1 and 15.2 (pg. 556), respectively. JIT success stories are impressive, but you should realize that not everyone agrees that JIT is the panacea for all ills. Before proceeding, take some time to study these exhibits. JIT goes beyond production planning and control. However, JIT can have a profound impact on the production, planning, and control process. Especially in repetitive manufacturing operations where inventories of raw materials are maintained, the use of a pull approach can greatly reduce the need for capacity requirements planning and detailed materials requirements planning.

Record Manufacturing Events

(*Figure 15.1, pg. 546, bubble 5.0*) As previously indicated, the process of recording information about the manufacturing activities (step 5.0) is highly automated. The process used to collect this data is often called *shop floor control*. The **shop floor control (SFC) process** is devoted to monitoring and recording the status of manufacturing orders as they proceed through the factory. The shop floor control process also maintains work center status information showing the degree ahead or behind schedule and utilization levels. As each operation is finished, this fact is reported to SFC through

EXHIBIT 15.1 Just-in-Time (JIT) Objectives

- *Zero defects:* Products are designed to be defect-free and to eliminate the need to inspect the product. In fact, the **total quality control (TQC)** approach to manufacturing, a subset of JIT, places responsibility for quality in the hands of the builder rather than in those of the inspector.
- *Zero setup times:* For instance, one world-class automobile manufacturer can change from one car model to another in 2.5 minutes, including complete retooling.
- *Small lot sizes:* Continuous flow operations are designed so that material does not sit idle and machine utilization is maximized (95 percent utilization is not uncommon).
- *Zero lead times:* As mentioned earlier, the goal is to eliminate the nonvalue-added (i.e., wasted in moving, waiting, and inspecting activities) portion of the total lead time.
- *Zero inventories:* In successful JIT installations, a goal is to maintain only enough inventory to satisfy demand for a few hours or days.

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EXHIBIT 15.2 Just-in-Time (JIT) Implementation Features

- Arranging the factory in U-shaped work cells to optimize material flow.
- Assigning one worker to multiple machines.
- Giving production workers the responsibility and authority to stop the production line if they are running behind schedule or if they discover defective parts.
- Requiring that the daily schedule for each part or assembly remains nearly the same each day.
- Developing close working relationships with vendors to ensure that they deliver quality raw materials on the promised delivery dates. In effect, vendors are supposed to serve as extended storage facilities of the company. We alluded to these relationships when we discussed choosing a vendor and deciding when and how much to purchase in Chapter 12.
- Simplifying the process for tracking the movement of goods through the factory. JIT is often called a *kanban* process, a name taken from the Japanese word for ''card.'' As such, the simple kanban or *move ticket* replaces the *manufacturing order* and *route sheet* of the past.

a *completed move ticket*, and updates are made to the *open MO data* and the *work center status data*. When the final operation in the sequence is finished, the MO is removed from the open MO data, and the inventory process is advised to add the quantities (and costs) to its finished goods records.

Through automation, the shop floor control process is able to collect valuable real-time data that can be used for immediate feedback and control. Automated data collection might involve obtaining information by scanning a *bar code* label attached to the product, coupled with entering quality and quantity information through workstations located on the factory floor. Often, the time needed to key-enter information about the operator is greatly shortened by reading those data from an employee badge inserted in the workstation.

Information also is collected about the time worked by laborers on each production task. Although old-fashioned paper time tickets may be used to enter data into the time records, more likely this process also will be automated through scanning employee badges and touching a few places on a computer touch screen to indicate the completion of manufacturing tasks. This same information becomes the necessary input for the payroll process. Finally, as additional raw materials are needed or unused raw materials are returned to the storeroom, raw materials issue and return notices will be recorded.

Generate Managerial Information

The data provided by the IPP system is vital to management of the global enterprise. Figure 15.6 shows how data collected through SFC, coupled with financial data available through other systems, help populate the enterprise database providing key information for both managing the IPP and also for driving other processes.

Because automation is used to collect data, it is generally available in real-time. For example, information about actual machine time used at a work center, collected after the move ticket is scanned following the operation, can be compared with standards from the routing master to give real-time information about variances from standard for that work center before the product is even completed. In this way, managers can take corrective action *before* they receive formal variance reports.

Key manufacturing decision-making outputs from the enterprise database include the following:

- Throughput time information derived by identifying start and completion times for manufacturing orders

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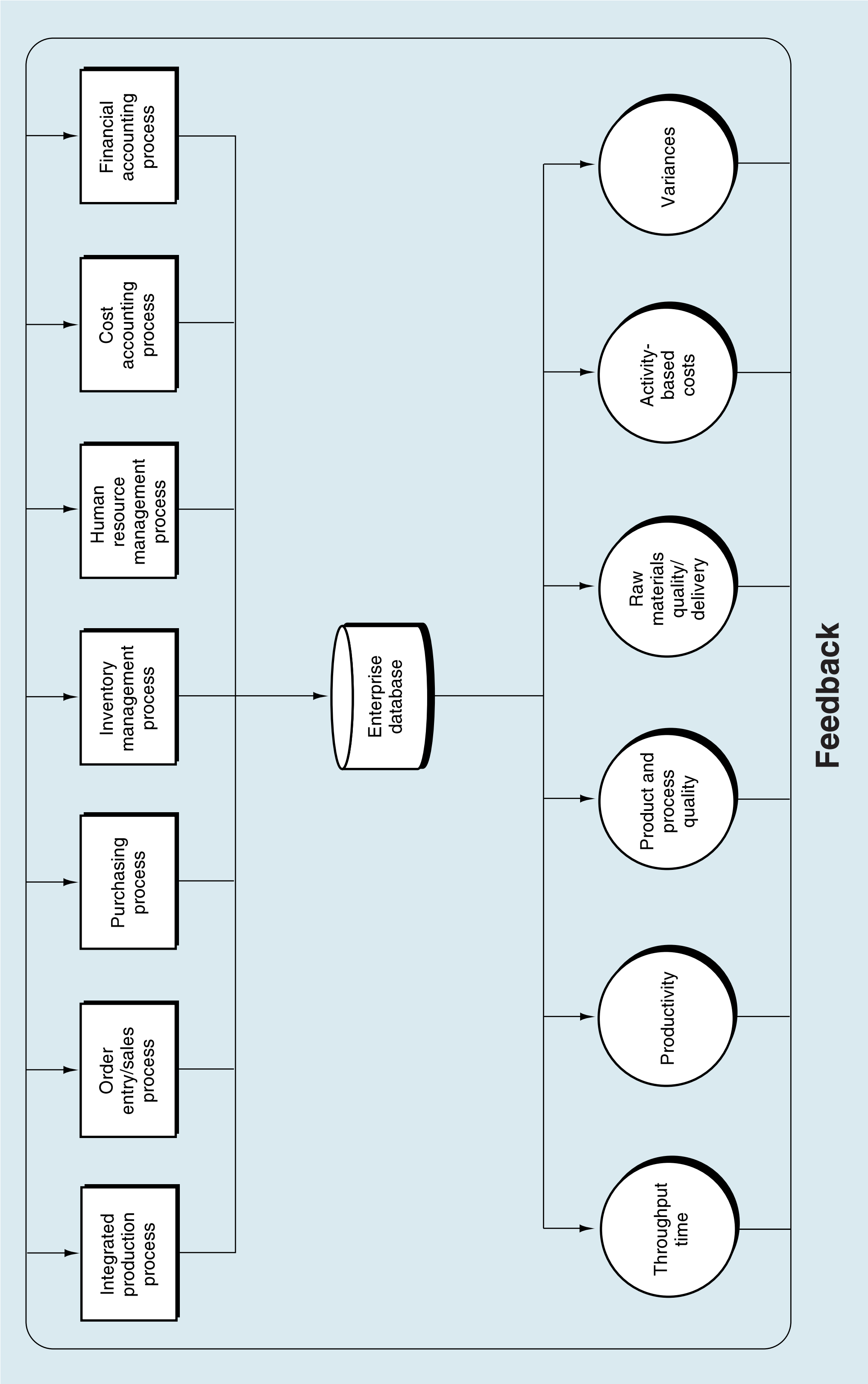
FIGURE 15.6 The IPP Role in Generating Managerial Information



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- Productivity information related to labor, machines, and materials derived by comparing the standard allowance for actual production outputs to the actual levels of labor machine time and materials used
- Quality information showing actual product quality levels achieved as well as machine and process performance
- Activity-based cost information showing the costs to perform activities at each work center as well as actual cumulative costs of producing subassemblies and final products
- Information about raw materials, including quality and on-time delivery
- Other cost accounting information such as variances discussed in the next section

This information provides vital feedback for improving the IPP as follows[5]:

- Information about productivity, product quality, and activity costs can all feed back to the product and process design process to help engineers design more cost-effective products and production processes (step 1.0).
- Better information about production times can be used to develop more effective production schedules and detailed production plans (steps 2.0 and 4.0).
- Information about raw materials quality and delivery can help improve timing of RM orders (step 3.0).
- Information about machine and labor utilization levels can be used to identify, manage, and possibly eliminate unneeded capacity (step 4.0).
- Information linking quality and machine performance can be used to develop better strategies for operating machines and developing machine maintenance plans.

In addition to using this information for production decision making, the data also is used in other business processes as follows:

- The order entry/sales process uses information about actual throughput times to determine necessary lead times for quoting future deliveries.
- The human resources management process uses information about labor productivity and utilization to determine future staffing levels and specific labor needs.
- The purchasing process uses feedback about productivity and quality of raw materials inputs to assess supplier effectiveness at delivering promised levels of quality.
- The inventory process uses feedback about lead times and throughput times to revise reorder points.

One component of management information collected about the IPP is variance information used in monitoring efficiency and adherence to production plans. This information also can help companies identify better strategies for managing tradeoffs between cost of inputs and productive use of these inputs. The process of collecting and processing variance information is described in more detail in the next section as an example of how data collected throughout IPP is combined with other data in the enterprise database to produce useful decision-making information.

Cost Accounting: Variance Analysis

ENTERPRISE SYSTEMS

CONTROLS

Variance analysis is the process of comparing actual information about input costs and usage to standards for costs and usage for manufacturing inputs. Although some criticism has been leveled at the process, when used in proper context, variance analysis is an important control tool. When computed in real-time, variances help manufacturing

5 The "steps" in this list refer to the process bubbles in the level 0 DFD of the IPP in Figure 15.1, pg. 546.

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managers monitor production processes to determine that they are performing as expected. Taking a longer-term view, variances can be monitored to assess the interplay between costs of various inputs and efficient use of these inputs.

The level 0 DFD in Figure 15.7 (pg. 560) shows the steps in the process of performing *variance analysis* using a standard costing system. We chose standard instead of actual costing for our illustration because this system is more prevalent in *current* practice. Recall from Table 15.1 (pg. 544), however, that with ERP systems, some companies are abandoning standard costing and returning to actual cost systems. Let's now examine the DFD, bubble by bubble.

Record Standard Costs

(*Figure 15.7, pg. 560, bubble 1.0*) At the time that each manufacturing order is released to the factory, a record is normally created in the *work-in-process inventory data*. At that point, the record contains identification data (job number, end product description, quantity to be produced, start date, etc.). Think of the work-in-process inventory data as serving as a *subsidiary ledger* in support of the work-in-process inventory *control account* in the general ledger.

The standard cost master data contains quantity standards (RM quantity, DL hour, and machine hour allowances per FG unit) and price standards (standard purchase price per unit of RM, standard labor rates per hour, etc.).

The data flow "Move ticket data" entering bubble 1.0 occurs at the completion of *each* operation until the job is completed. Each completed move ticket triggers an update to the work-in-process inventory data for the standard cost of labor and overhead allowed for that particular operation. Standards are obtained from the standard cost master data.

When CRP released the MO, it sent a raw materials requisition to the inventory process. The requisition authorized the storeroom to issue the *standard* RM quantities allowed for the MO. After the RMs have actually been issued by the storeroom, the inventory process notifies cost accounting that this has occurred (through the data flow "Standard RM issue notice"). This notification prompts an update to the work-in-process inventory data for the standard cost of the materials (i.e., standard quantities times standard prices).

Figure 15.8 (pg. 561) shows the raw materials that have been issued into production. In a traditional paper process, the issue notice may physically be a copy of the materials requisition, dated and signed by the storeroom clerk to signify that the goods were issued. Through the data flow "GL standard costs applied update," process 1.0 notifies the general ledger to make the appropriate entry to apply standard costs to WIP.[6]

Compute Raw Material Quantity Variance

(*Figure 15.7, pg. 560, bubble 2.0*) In the discussion of bubble 1.0, you learned that RMs were first issued to production in *standard* quantities. If additional materials are later issued to complete the MO (unfavorable condition) or unused materials are returned to stock (favorable usage variance), these events are reported through the data flows "Excess RM issue notice" and "RM returned notice," respectively. The usage variance[7]

6 A discussion of general ledger standard costing entries is beyond the scope of this chapter. Your managerial/cost accounting courses should cover this topic.

7 We assume that the RM *price* variance is isolated when the materials are *purchased. Therefore, computing the purchase price variance is a function of the inventory process.*

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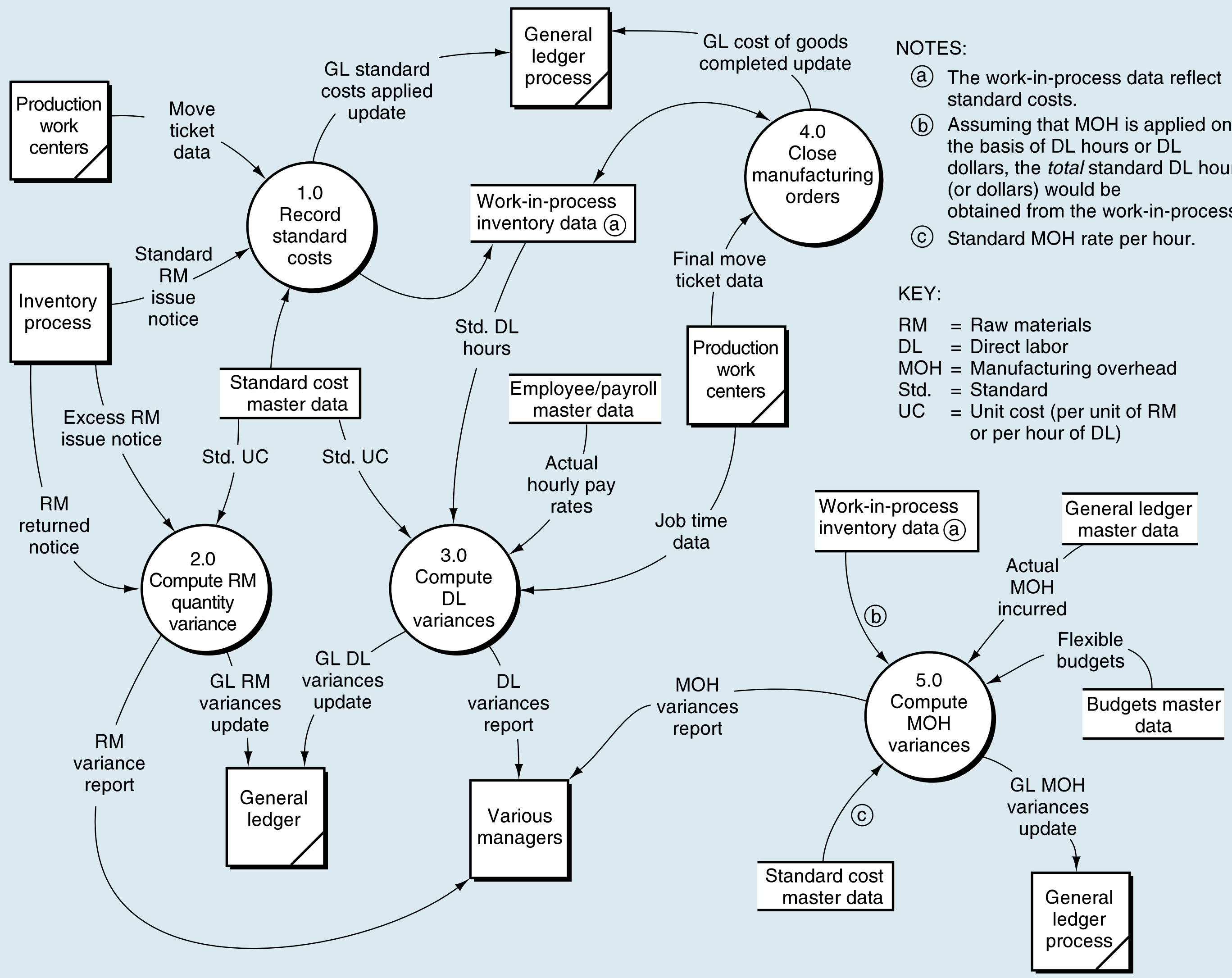
FIGURE 15.7 Level 0 DFD—Cost Accounting: Variance Analysis



NOTES:

ⓐ The work-in-process data reflect standard costs.

ⓑ Assuming that MOH is applied on the basis of DL hours or DL dollars, the *total* standard DL hours (or dollars) would be obtained from the work-in-process file.

ⓒ Standard MOH rate per hour.

KEY:

RM = Raw materials
DL = Direct labor
MOH = Manufacturing overhead
Std. = Standard
UC = Unit cost (per unit of RM or per hour of DL)

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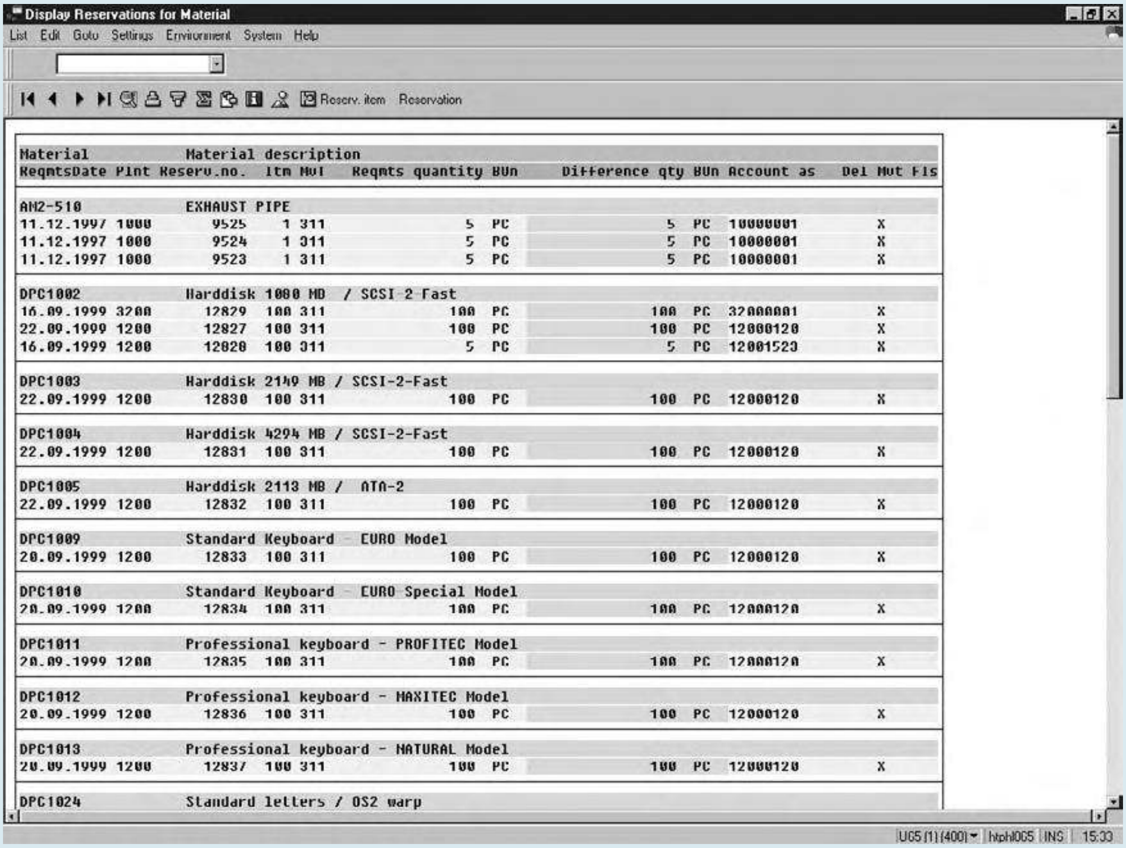
FIGURE 15.8 Materials Planning (SAP®)



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is calculated by multiplying the quantities by standard unit costs from the standard cost master data. This variance is then reported to the general ledger and to the appropriate managers.[8]

Compute Direct Labor Variances

(Figure 15.7, pg. 560, bubble 3.0) The inputs to bubble 3.0 are available through electronic capture or from data stores existing within the system. The actual hours an employee works on a job is the job time data. This information can largely be captured with an employee card swipe and a bar code scan of the job order. Employee pay rates are obtained from the *employee/payroll master data* (see Chapter 14). For each operation required to complete the job, the standard hours for the operation are retrieved from the work-in-process data; the standard cost master data provides the standard labor rates per hour. As in the case of raw materials, the direct labor variances are computed and reported to the general ledger and the various managers.

---

8 Reporting variances to the general ledger and to various managers is shown happening three times in Figure 15.7 (i.e., from bubbles 2.0, 3.0, and 5.0). Obviously, the three might be combined into a single update notice to the general ledger and one variance report to each manager.

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Close Manufacturing Orders

(*Figure 15.7, pg. 560, bubble 4.0*) As discussed in an earlier section, the *final move ticket data* marks the end of the conversion process and the movement of goods to the FG warehouse. Information processing activities that result from the final move ticket are the following:

- Close the cost record maintained in the work-in-process inventory data, and compute the standard cost of the goods completed.
- Through the data flow "GL cost of goods completed update," notify the general ledger to make the appropriate entries.

Compute Manufacturing Overhead Variances

(*Figure 15.7, pg. 560, bubble 5.0*) Process 5.0 is triggered by a temporal event and is performed at the end of an accounting period (e.g., each month) rather than being triggered by a specific data flow from an external entity. To compute the manufacturing overhead variances, process 5.0 would do the following:

- Obtain the *flexible budget* from the budgets master data; the budget amount is based on the standard hours allowed to complete the actual finished goods output for the period.
- Retrieve the figures for actual MOH incurred from the general ledger master data.
- Access the work-in-process data to determine the standard hours charged to *all* jobs during the period; these hours would be multiplied by the standard MOH rate per hour from the standard cost master data.

Once again, the variances are reported to the general ledger and the appropriate managers.

Inventory Management

CONTROLS

In addition to the management of human resources, inventory management is another major area of concern for manufacturers—particularly those that are operating in JIT environments. Manufacturers must estimate needed levels of inventory to meet customer demands, often at a moment's notice. As illustrated through our description of IPP, a major challenge for the inventory manager is determining appropriate levels of raw materials, subassemblies, and finished goods inventory to assure that production can be maintained and finished goods delivered in a timely manner. Information about finished goods is an important input to the production scheduling process, whereas raw materials and subassemblies inventory variables play an important role in materials requirement planning. Balancing inventory levels to satisfy customer demands in this type of environment, where customer demands are uncertain and production processes are complex and fast-paced, can be a challenging process. For example, if you are a manufacturer of specialized parts for a large automaker, such as General Motors, and you cannot consistently fill orders in the desired time frame, you probably will not be a partner company for long! Similarly, companies such as HP and Lenovo™ may require suppliers to ship orders for products such as CD-ROMs within just four hours after orders are placed.

The purpose of this section is to give you a better understanding of how the inventory management process supports the information needs of those responsible for managing it. The section provides a sample of the kinds of decisions made by the warehouse manager and the supervisor of the inventory control department. We also

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briefly discuss some of the risks associated with inventory control. We conclude this section with an exploration of the control processes for both safeguarding and efficiently using inventory.

Decision Makers and Types of Decisions

Table 15.3 presents a *sample* of the types of decisions the warehouse manager and the supervisor of the inventory control department confront. Concentrating on the decisions presented in the table allows you to see both the opportunities and the challenges that typically face those managers. We'll discuss one of those decisions next.

Making the first decision listed in Table 15.3, *the proper balance of inventory to achieve optimal customer service and optimal investment in inventory*, requires information from a number of sources, including customer sales and services (Chapter 10), the master production schedule (MPS), materials requirements planning (mrp), and the warehouse manager. Recall from Chapter 10 that the order entry/sales process often captures data regarding customer needs, customer satisfaction, and so forth. This information may impact production and capacity planning schedules.

From the standpoint of the production manager, inventory availability is a vital element in the ability to maintain production requirements for meeting customer demands. Consequently, this manager's inclination may be to inflate the inventory investment. However, an unwarranted increase in an organization's inventory investment can result in lowering its return on investment and decreasing its space utilization. Thus, data emanating from several functional areas must be gathered and analyzed before an organization can achieve an optimal inventory balance. An optimal inventory balance often translates to a level of inventory availability that is commensurate with some predetermined level of production capacity and upper bounds on expectations of customer orders.

Part of the responsibility of the inventory control manager is to help manage the composition of an organization's inventory investment. This responsibility may include adjusting the inventory balance so that it better fulfills flexible manufacturing needs or so that it turns over more quickly. Unfortunately, the inventory processes of many organizations may not provide the inventory control manager with the information needed to determine whether the inventory investment is out of balance. Take some time now to examine the remainder of Table 15.3.

TABLE 15.3 Sample of Decision Making Relative to Inventory

Organizational Decision Makers	Decisions
Supervisor of inventory control department	The proper balance of inventory to achieve optimal customer service and optimal investment in inventory The proper models for measuring inventory performance The particular inventory items that require reordering How much inventory to reorder When to reorder inventory Who to order inventory from
Warehouse manager	Best techniques for maintaining physical control over inventory as it is received, while it is stored, and as it is shipped Schedules for taking physical inventory counts How and where inventory should be stored

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The Fraud Connection

CONTROLS

Before we discuss internal control as it relates to the inventory process, let's first consider the topic of inventory fraud. Inventory is a primary domain for *management fraud*. Although numerous cases of inventory theft could be presented here, we confine our discussion in this section to management fraud connected with inventory. That is, we will revisit a topic introduced in Chapter 7—namely, "cooking the books" by fraudulently misstating inventory in the financial statements.

The problem of inventory manipulation—both its frequency and the materiality of the financial statement misstatements—is massive. One authority states that inventory fraud has grown fourfold in five years and is one of the biggest single reasons for the proliferation of accounting scandals and their associated lawsuits. One such case is Laribee Wire Manufacturing Co., a New York copper-wire maker. Suffering from a huge debt and declining sales, Laribee borrowed $130 million, a major portion of the loan collateral being its reported inventories of copper rod. After the firm filed for bankruptcy court protection a year later, it was discovered that much of its inventory either did not physically exist or was on the books at inflated values. It is estimated that the inventory fraud contributed $5.5 million to Laribee's before-tax profits.

Although this chapter focuses on manufacturing and production processes, it should be noted that inventory control issues are similar for merchandising firms. Unfortunately, merchandising organizations are perhaps even more susceptible to inventory fraud. One illustrative case of merchandising inventory fraud is that of Phar-Mor Inc., the deep-discount drugstore chain. Phar-Mor kept inventory on its books that had already been sold and created fictitious inventory at several of the chain's stores. In a suit filed against Phar-Mor's auditing firm, one of its major stockholders contended that the company's balance sheet falsified and overstated inventory by more than $50 million!

In 1994, the AICPA issued *Practice Alert No. 94–2: Auditing Inventories—Physical Observations*. This *Practice Alert* includes the following examples of inventory fraud, among others:

- Including items in physical inventory counts that are not what they are claimed to be, or including nonexistent inventory. Examples are counting empty boxes, mislabeling boxes that contain only scrap or obsolete goods, and diluting inventory so that it appears to be of greater quantity than it actually is (e.g., adding water to liquid inventories).
- Counting obsolete inventory as salable or usable.
- Counting merchandise to which the company does not have title, such as consigned goods and "billed and held" inventory.[9]
- Increasing physical inventory counts for those items that the auditors did not test count.
- Double-counting inventory that is in transit between locations, or moving inventory and counting it at two locations.
- Arranging for false confirmations of merchandise purportedly held by others, such as inventory in public warehouses or out on consignment.
- Including inventory for which the corresponding payable has not been recorded.
- Manipulating the reconciliations of inventory that was counted at other than the financial statement date. It is not uncommon to perform physical inventory taking

9 Billed and held inventory is common in certain industries, such as the textile industry. Under the bill and hold arrangement, the seller invoices the buyer for purchased goods—thereby passing title to the buyer at the time of billing—but then holds the inventory at the seller's location until such time that the buyer issues shipping instructions.

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on a "cycle" basis. That is, items are counted at staggered times throughout the year. When counts are done after the financial statement date, the counted quantities then must be reconciled to year-end quantities by adding purchases and subtracting sales made between the count date and year-end. Attempts to manipulate these reconciliations entail either overstating purchased quantities or understating sold quantities to make it appear that there is a greater on-hand balance at year-end than actually exists.

- Programming the computer to produce false tabulations of physical inventory quantities or priced summaries.[10]

Inventory Process Controls

CONTROLS

The criticalness of maintaining adequate inventory levels should be apparent at this point. Keep in mind, however, that we must balance the desire for high inventory levels with the need to avoid both excessive inventory carrying costs and leftover supplies of materials that are no longer required in revamped production processes. As such, inventory process controls are primarily oriented toward operational (i.e., effectiveness and efficiency) and security objectives. We focus here on three categories of control goals:

1. *Effectiveness of operations* relative to the following goals (note that these goals address the concepts discussed earlier in the chapter; namely, *optimizing* the inventory investment):

   a. To maintain a sufficient level of inventory to prevent stockouts
   b. To maintain a sufficient level of inventory to minimize operational inefficiencies
   c. To minimize the cost of carrying inventory

   Sample controls in the area categorized as effectiveness of operations might include the following:

   a. *Perpetual inventory records:* Maintenance of a continuous record of the physical quantities maintained in each warehouse facilitates inventory management. The receipt or shipment of each item is recorded in the inventory master data to facilitate monitoring of inventory levels and to minimize stockout risks and production interruptions. *Radio frequency identification (RFID)* tags can be attached to inventory items to track their movement throughout the warehouse and even through the entire supply chain. A perpetual inventory process helps to achieve the goals by providing an up-to-date record of the status of the firm's overall inventory investment, including an account of the activity rate of each inventory item. Thus, fast-moving inventory can be identified to help prevent stockouts. Additionally, monitoring of slow-moving or excessive inventory can help minimize the cost of carrying inventory.
   b. *Just-in-time materials acquisition:* JIT acquisition essentially eliminates the risk of overstocks while also minimizing inventory carrying costs. Suppliers should be careful in selecting supplier partners, however, to assure they can deliver on a timely basis when demands for raw materials arise.

10 Division for CPA Firms—Professional Issues Task Force, *Practice Alert No. 94–2: Auditing Inventories—Physical Observations* (New York: American Institute of Certified Public Accountants, July 1994).

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E-BUSINESS

c. *Internal transfer procedures:* Often, materials and finished goods inventory will be stored in multiple warehouse or plant locations. As described earlier, with *global inventory management*, needs for raw materials or finished goods orders would initially be satisfied with excess inventory available through transfers from other locations. Only when inventory needs cannot be fulfilled through internal transfers should procedures be initiated for requisitioning materials from suppliers or initiating increased production scheduling. Coordination between warehouses and plants helps maintain more optimal inventory levels and helps avoid inventory outages.

2. *Efficient employment of resources:* Sample controls in the area categorized as efficiency might include the following:

   a. *Just-in-time materials acquisition:* JIT inventory acquisition, when automated through *EDI* or other related approaches, can improve the efficiency of the inventory process by reducing the amount of manual labor necessary to determine when to reorder materials inventory. *Vendor managed inventory (VMI)* can shift the burden of the reordering decisions to the suppliers.

   b. *Warehouse bin location:* This plan calculates the approximate amount of space to devote to each inventory item. It also analyzes the total warehouse space available to determine *where* to locate each item to increase requisition picking efficiency.

3. *Resource security:* The resources of interest here are the raw materials, work-in-process and finished goods inventory assets, and the information resources stored in the inventory master data. Control plans should be in place to prevent unauthorized accessing, copying, changing, selling, or destruction of the inventory master data. Of equal importance, plans should be in place to prevent theft or unauthorized sale of merchandise inventory. Sample controls in the area categorized as resource security might include the following:

   a. *Periodic physical inventory counts:* Used in conjunction with a perpetual inventory process, this control plan assists in protecting materials, work-in-process, and finished goods inventory by providing the warehouse manager or the inventory control supervisor with a record of the actual (on-hand) balance of each item of inventory. This record can be compared to the corresponding perpetual records to detect any differences between the two balances. Differences between the balances may suggest the possibility of pilferage, which, in turn, exposes an organization to the risk of not achieving the control goal of resource security over its inventory. *RFID* tags can make the inventory count process more efficient and accurate.

   b. *Locked storerooms:* Locked storerooms contribute to the achievement of the operations system control goal of securing inventory. Over the years, a number of organizations have experienced a high rate of theft by employees because of inadequately secured rooms where materials and finished goods inventory are stored. In addition to theft prevention, when inventory is secured, a company can make sure the use of items is properly recorded, yielding available inventory when needed and ensuring operations efficiency. As a control plan, locked storerooms limit access to an organization's inventory to authorized employees only.

One final note before leaving the area of inventory control is the parallel between the processes we have discussed in this section for integrated production processes and that used in merchandising environments. Inventory acquisition and product sales have

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been previously discussed in Chapters 10 through 13. However, we did not focus on inventory control in those chapters, in part because the procedures would be redundant with the discussion presented in this section. The same concerns over operational (i.e., effectiveness and efficiency) and security risks also exist in merchandising environments, and similar controls to those discussed in this section should be implemented to control the receipt, storage, and distribution of merchandise as it is stored in or moved between various stores and warehouses.

Summary

Clearly, the integrated production process represents an excellent example of the power of enterprise systems. The process integrates tightly with nearly every other process described so far, especially order entry/sales, purchasing, HR management, payroll, and inventory management. With costs generated in production representing a significant portion of operating costs for manufacturing businesses and with huge pressures related to controlling product lifecycle costs, increasing innovation, and decreasing time to market, the importance of enterprise systems for managing the process is paramount. Potential costs from poor information include lost sales due to stockouts; excess finished goods inventories; delays due to poor planning for labor, material, and production resources; excess raw materials due to poor forecasting; and poor reputation resulting from poor quality.

Accounting systems designers face significant challenges in meeting financial accounting needs while taking advantage of the vast array of information production capability in enterprise systems to generate more useful managerial information. In particular, they will be expected to take a lifecycle costing approach and provide valuable information in all stages of the value chain:

- Take an active role in the early stages of product development. This role should emphasize cost-reduction activities.
- Provide more advice, not only during development, but also throughout the entire manufacturing process. Some people have even suggested that cost accountants should spend most of their time on the factory floor performing value analysis to prevent variances from occurring in the first place.
- Develop nontraditional measurements that can help in managing the business, and share that information with the workers on a timely basis. Measures might include such factors as employee morale, product quality (perhaps in the form of warranty data), disaggregated production and scrap data by machine or by work center, schedule and delivery attainment, throughput time, and space devoted to value-added activities versus nonvalue-added activities.
- Develop new standard cost systems that will focus on quality and production as well as price and efficiency. These updated cost systems would employ input/output analysis rather than focus only on inputs as the conventional standard cost system does.
- Design new ways to evaluate investments. Traditional tools such as *return on investment (ROI)* and *net present value* analyses have proved inadequate for making decisions about major commitments of resources to enterprise systems technology, especially the important cross-functional systems such as customer relationship management, supply chain management, and product lifecycle management so critical for managing globally diverse manufacturing operations. The traditional cost justification methods must be supplemented with an analysis of intangible benefits, including items such as improved shop floor flexibility, reduced manufacturing lead time, faster delivery of

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product to market, improved product quality, improved product design, better customer service, and similar factors.

One final thought about how the accountant can take a leadership role in manufacturing companies concerns that of designing *simplified* processes. Part of simplification involves making the data we capture in the information system easier to access. Another part requires that we be constantly alert to opportunities to reduce paperwork. The trend toward *paperless processes* must accelerate to keep pace with other technological changes occurring in production processes.

Key Terms

throughput time
push manufacturing
pull manufacturing
cellular manufacturing
subassemblies
available to promise planning
capable to promise planning
activity-based costing
lifecycle costs
computer-aided design (CAD) and computer-aided engineering (CAE)
bill of materials
parts master
routing master
computer-aided process planning (CAPP)
work center master
workstation
work center
master production schedule (MPS)
global inventory management
production, planning, and control
materials requirements planning (mrp)
time-phased order requirements schedule
exploding the BOM
capacity requirements planning (CRP)
manufacturing orders (MOs)
move tickets
raw materials requisition
manufacturing resource planning (MRP)
flexible manufacturing systems (FMS)
computer-aided manufacturing (CAM)
automated storage and retrieval systems (AS/RS)
automated guided vehicle systems (AGVS)
just-in-time (JIT)
total quality control (TQC)
shop floor control (SFC) process
variance analysis

Review Questions

RQ 15-1 How has global competition impacted the domestic manufacturing environment? How can technology help domestic companies compete?

RQ 15-2 Explain the three key drivers of complexity in manufacturing operations in the new millennium.

RQ 15-3 Describe the three key characteristics of companies that successfully manage global complexity.

RQ 15-4 What is the role of product innovation and product lifecycle management in helping manufacturing companies compete in the global arena?

RQ 15-5 What are the differences between push manufacturing and pull manufacturing?

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RQ 15-6 How does supply chain management help organizations improve their competitiveness, especially in a manufacturing organization?

RQ 15-7 What important trends have occurred during the past few decades in cost management and cost accounting?

RQ 15-8 What is the role of the order entry/sales and inventory management processes in the IPP?

RQ 15-9 What are the steps in the IPP, and what happens at each step?

RQ 15-10 Describe the importance of both activity-based costing and product lifecycle costing for managing IPP.

RQ 15-11 From the inventory perspective, what is the advantage of producing goods as customer orders are received?

RQ 15-12 What is global inventory management, and how can it be used to increase the capability of a company to deliver goods on a timely basis and manage inventories?

RQ 15-13 a. How are a bill of material (BOM) and a routing master similar? How are they different?

b. What does ''exploding a bill of material'' mean?

RQ 15-14 What are some of the components of flexible manufacturing systems, and how do they work?

RQ 15-15 What are some of the characteristics and advantages of a JIT system?

RQ 15-16 How are materials requirements planning, detailed capacity requirements planning, and shop floor control similar? How are they different?

RQ 15-17 How is information generated about the IPP used for managing the IPP as well as other business processes?

RQ 15-18 What are the key processes, data, and data flows in the cost accounting system for variance analysis of a manufacturer that uses a standard cost system?

RQ 15-19 Why is inventory management and control important to the manufacturing and production processes?

RQ 15-20 How would a company gain (short term) from a fraudulent overstatement of inventories?

Discussion Questions

DQ 15-1 This chapter discusses the complexities of competing in a highly competitive global manufacturing environment. Discuss how enterprise systems can help an organization streamline its processes and become more competitive.

DQ 15-2 What industry do you believe is a leader in enterprise systems implementations? Discuss what you think are the major contributing reasons for that leadership.

DQ 15-3 Table 15.1 (pg. 544) presents a summary of trends in cost management and cost accounting that have occurred during the past two decades.

a. Which trends do you consider most significant? Explain your answer.

b. The first footnote to Table 15.1 indicates that there are additional cause-and-effect relationships that could be shown between the items in the right column and those in the left column. Give several examples (with explanations) of those other relationships.

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DQ 15-4 ''A company cannot implement a just-in-time (JIT) process without making a heavy investment in computer resources.'' Do you agree? Discuss fully.

DQ 15-5 ''A company cannot implement manufacturing resource planning (MRP) without making a heavy investment in computer resources.'' Do you agree? Discuss fully.

DQ 15-6 ''A company cannot implement a flexible manufacturing system (FMS) without making a heavy investment in computer resources.'' Do you agree? Discuss fully.

DQ 15-7 A main goal of just-in-time (JIT) is zero inventories.

a. Assuming your company does not aspire to JIT and has $1,000,000 in raw materials in stock. Identify cost that may be incurred to maintain the inventory level.
b. Now assume that you implement JIT, and your raw materials in stock drop to zero. Explain how you expect this change to impact your income statement and balance sheet.

DQ 15-8 Without redrawing the figure, discuss the changes that would occur in Figure 15.7 (pg. 560) if the company used an actual costing system instead of a standard cost system.

DQ 15-9 Discuss how the inventory control process goals support the production planning process and the risks to the production process if such controls are not in place. Do not limit your discussion to losses from fraud.

Problems

P 15-1 Refer to the level 0 DFD in Figure 15.1 (pg. 546). Study the portion of the figure and accompanying narrative that deals with the product and production process design process *only*. Prepare a level 1 DFD for the product and production process design process (bubble 1.0) *only*.

P 15-2 Refer to the level 0 DFD in Figure 15.1 (pg. 546). Study the portion of the figure and accompanying narrative that deals with the materials requirements planning process *only*. Prepare a level 1 DFD for the materials requirements planning process (bubble 3.0) *only*.

P 15-3 Refer to the level 0 DFD in Figure 15.1 (pg. 546). Study the portion of the figure and accompanying narrative that deal with the capacity requirements planning process *only*. Prepare a level 1 DFD for the capacity requirements planning process (bubble 4.0) *only*.

P 15-4 Consider all of the data stores shown in Figure 15.1 (pg. 546). Draw an entity-relationship diagram showing the database for the IPP based on the data stores shown in the figure. You do not need to include cardinalities.

P 15-5 Refer to the level 0 DFD in Figure 15.1 (pg. 546). Study the portion of the figure and accompanying narrative that deal with the shop floor control process *only*. Prepare a level 1 DFD for the shop floor control process (bubble 5.0) *only*.

P 15-6 Refer to the DFD in Figure 15.7 (pg. 560). Study the portions of the figures and the accompanying narrative that deal with the cost accounting—variance analysis system *only*. Prepare a detailed systems flowchart for the cost accounting—variance analysis system *only*.

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P 15-7 Study Figure 15.7 (pg. 560), showing the level 0 DFD of the cost accounting system. Note that the raw materials and finished goods inventory processes are *outside* the context of the system shown (i.e., the DFD covers work-in-process inventory only).

a. Draw a *context diagram* for the system as it *currently* exists.
b. Assume that both the raw materials and finished goods inventories are *within* the system context. Prepare a *context diagram* for the revised system, and redraw Figure 15.7 to reflect the revised system. Ignore the ordering of raw materials from vendors; start the raw materials process with the receipt of goods. Also ignore the issue of finished goods. Keep the assumption that the company uses standard costing for all inventories.

P 15-8 Study Figure 15.7 (pg. 560), the level 0 DFD of the cost accounting system for a company using standard costing. Redraw Figure 15.7, assuming that the company uses an actual cost instead of a standard cost system.

P 15-9 Figure 15.7 (pg. 560) shows several data flows running to the general ledger (GL) for the purpose of updating the general ledger master data.

a. For each of the following data flows in Figure 15.7, show the journal entry (in debit/credit journal entry format, with no dollar amounts) that would result (make and state any assumptions you think are necessary):
   - GL standard costs applied update
   - GL RM variances update
   - GL DL variances update
   - GL MOH variances update
   - GL cost of goods completed update
b. What other standard cost accounting entries are not included in your answer to requirement a? Show those journal entries; describe *when* they would be made and *what* event they are recording.

P 15-10 Based on the inventory control process goals discussed in the chapter, explain the impact of using a periodic inventory process instead of a perpetual process. Be sure to also discuss how you would design the process to attempt to meet the same control objectives using this periodic process.

P 15-11 In many popular publications, the terms ''lean accounting'' and ''lean manufacturing'' are periodically used.

a. Research ''lean manufacturing'' and find out what concepts are conveyed by the term. How does lean manufacturing overlap with, and how is it different from, IPP?
b. Research ''lean accounting'' and find out what concepts are conveyed by the term. Compare and contrast what you find in Table 15.1 (Summary of Trends in Cost Management/Cost Accounting).

P 15-12 The chapter begins by discussing the global competition faced by manufacturing firms. Identify two companies in your local area—one that has thrived in a global market and one that has failed. Compare and contrast the companies. Based on your understanding of manufacturing and the

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failed company, identify strategies that might have helped the company be successful.

P 15-13 The chapter discusses fraud from an inventory perspective. Research inventory fraud cases, and write a paper on a case you find interesting (Your instructor will provide guidance regarding the paper's length). At a minimum, you should include the following items:

- A description of the organization
- The perpetrator(s) of the fraud
- A description of the method used to defraud
- An analysis of the missing control(s) that would have prevented the fraud
- The length of time the organization was deceived
- The impact over time (including monetary and other losses)
- The penalty received by the perpetrator(s)