MANUFACTURING PLANNING & CONTROL FOR SUPPLY CHAIN MANAGEMENT

THE CPIM REFERENCE

SECOND EDITION

F. ROBERT JACOBS | WILLIAM L. BERRY
D. CLAY WHYBARK | THOMAS E. VOLLMANN

Mc Graw Hill Education

Manufacturing Planning and Control for Supply Chain Management

The CPIM Reference

F. Robert Jacobs
Indiana University (Emeritus)

William L. Berry
The Ohio State University (Emeritus)

D. Clay Whybark
University of North Carolina (Emeritus)

Thomas E. Vollmann
International Institute for Management Development

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We dedicate this book to Professor Thomas E. Vollmann. Tom's enthusiasm and brilliance have influenced virtually every page of this book since the first edition was published in 1984. Tom is greatly missed by the author team and by the worldwide community of Operations Management colleagues of which he was a part. We are truly indebted to Professor Vollmann.

About the Authors

F. Robert Jacobs is an emeritus professor at the Kelley School of Business, Indiana University. He has served on the APICS board of directors and was a key author of the APICS "Body of Knowledge Framework." Mr. Jacobs is coauthor of previous editions of *Manufacturing Planning and Control for Supply Chain Management* and coauthor of *Operations and Supply Chain Management.*

William L. Berry is an emeritus professor at The Ohio State University and coauthor of previous editions of *Manufacturing Planning and Control for Supply Chain Management.*

D. Clay Whybark is an emeritus professor at the University of North Carolina and coauthor of previous editions of *Manufacturing Planning and Control for Supply Chain Management.*

Thomas E. Vollmann was a professor at IMD and coauthor of previous editions of *Manufacturing Planning and Control for Supply Chain Management.*

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PREFACE

Interest in learning about manufacturing planning and control (MPC) is at a very high level around the world. There are versions of this book in a number of different languages attesting to its popularity as a standard reference on the topic. APICS—the Association for Operations Management—has seen growing interest in its Certified in Production and Inventory Management (CPIM) exam over the past few years. The number of people taking the exam has grown, particularly in countries outside the United States. Further, many individuals are developing certification courses designed to efficiently teach the material to those wanting to take the exam. This APICS/CPIM edition of the book is especially designed for individuals studying for the exam.

The goal of this book has been to make it the definitive reference for MPC and the relationship between MPC and supply chain management. Thus, the treatment of the topics tends to be comprehensive and follows a unique framework. This book provides complete coverage of the MPC topics and many of the supply chain management topics covered in the CPIM exam. The exam is divided into two modules and, following this Preface, there are tables that show how the CPIM modules align with the material in this book.

This book makes a great reference for those studying for the exam by providing practice questions similar to those used for the exam. These questions are at the end of each chapter. There are different types of questions, including objective definition questions, short problems, and more comprehensive sets of questions based on a scenario. They are intended for practice for the exam.

A real advantage of this book is that it goes well beyond the basics and can be used as a desk reference long after the CPIM exam has been taken. The book has proven to be a useful reference for MPC for the past three plus decades. The original authors of the book were true founding thought leaders in the field. Of course, the book has been significantly updated over the years as technology has changed and as knowledge about how these things should be done has increased.

In a sense, this edition is designed to recognize the maturity of much of the material in this book. Since the first edition, published in 1984, the techniques and concepts in the book have developed to where most of the ideas are now commonly available in enterprise resource planning (ERP) systems. So, this edition presents the basic ideas in a significantly streamlined manner. Many readers of this book are just learning the material, and they will appreciate the book's concise presentation with clear examples. In addition, much of the "research"-oriented material from previous editions has been omitted. Finally, discussions of outdated ideas have been replaced with coverage of new ideas that are now commonly implemented in firms.

The first twelve chapters of the book provide a thorough coverage of manufacturing planning and control. In the spirit of previous editions of the book, the coverage is extensive and complete, yet as concise as is reasonable. In an effort to not confuse the reader, the use of "lingo" has been minimized, while introducing the vernacular of the operations and supply chain management professional. Terminology and the organization of the topics closely follow that used in the *APICS Dictionary* and in the *APICS Body of Knowledge Framework* (which was co-authored by an author of this book).

The last five chapters of the book focus on the integration of manufacturing with the supply chain. In these chapters, the emphasis is on the basic techniques and concepts, and they are covered in a manner that corresponds to how they are commonly implemented in ERP systems. Integration of MPC with the logistics and warehousing functions in the firm can no longer be an "arm's-length" activity. Speed and efficiency require tight integration of these activities with minimal inventory buffering. Complicating matters is the often-common outsourcing of the shipping and warehousing activities, which places complex supply chain-related demands on the MPC system.

The supply chain professional of the future needs a very strong understanding of the material in this book. Just as the professional accountant must understand the basics of assets, liabilities, the balance sheet, and the income and expense statements, together with the transactions that generate the data in the accounting systems, so too must the supply chain professional understand a set of basic techniques and concepts. The sales and operations plan, master schedule, material requirements planning, and distribution requirements planning records that tie the manufacturing function to the supplier on the inbound side and the customer on the outbound side in terms of material and inventory. Logic such as regression analysis, exponential smoothing, available-to-promise, material planning, and reorder points are the decision support tools that assist the professional in making rational decisions within the realm of manufacturing and supply chain planning.

This book is designed to be an essential resource for the new student of the field, those studying for the CPIM exam, and the practicing professional. Mastery of the contents provides a solid foundation on which comprehensive, firm-specific implementations can be developed. Even though each firm has unique requirements dependent on special supplier and market demands, a sustainable competitive advantage comes from taking an innovative approach to how material and inventory is managed. A comprehensive understanding of the key concepts and techniques available is essential to structuring and implementing the supply chain material and inventory planning systems used by the firm. This book is designed to support this understanding.

	Chapter																	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*Covered?*
CPIM Part 1 Exam																		
I. Business-Wide Concepts																		
a. Supply Chain Fundamentals	X	X													X			Yes
b. Operating Environments	X	X	X												X		X	Yes
c. Financial Fundamentals				X														Yes
II. Demand Management																		
a. Market Driven			X											X				Yes
b. Voice of the Customer			X															Partial
c. Customer Relationship Management (CRM)			X															Yes
III. Transformation of Demand into Supply																		
a. Product and Process Design	X												X					Yes
b. Capacity Management										X	X							Yes
c. Planning	X				X		X			X								Yes
IV. Supply																		
a. Inventory		X					X	X	X				X	X	X	X		Yes
b. Purchasing Cycle																	X	Yes
c. Distribution														X	X			Yes

	Chapter																	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*Covered?*
CPIM Part 2 Exam																		
I. Master Planning of Resources																		
a. Demand Management			X	X														Yes
b. Sales and Operations Planning					X	X												Yes
c. Master Scheduling							X											Yes
II. Detailed Scheduling and Planning																		
a. Inventory Management			X					X	X				X			X		Yes
b. Planning Material Requirements to Support the Master Schedule								X	X					X	X		X	Yes
c. Planning Operations to Support the Priority Plan		X	X							X	X	X	X					Yes
III. Execution and Control of Operations																		
a. Execution of Operations: Prioritizing and Sequencing Work to Be Performed								X		X	X	X						Yes
b. Control of Operations: Executing the Plans, Implementing Control, and Reporting Results of Activities Performed								X				X	X					Yes
c. Quality, Communications, and Continuous Improvement: Performance Reporting and Feedback											X		X					Partial
IV. Strategic Management of Resources																		
a. Understanding the Business Environment and Developing Corporate Strategy	X														X		X	Partial
b. Developing the Operations Strategy	X																X	Yes
c. Implementing the Operations Strategy Monitoring Performance and Implementing Change	X												X					Partial

ACKNOWLEDGMENTS

As with all of the previous editions, we have benefited from the comments of the many reviewers and users of the book. We are indebted to all of the loyal readers who have given us literally thousands of ideas about how things should be explained, concepts that should be included, and stories about how it is done in practice. The process of change and updating is continuous with a book of this type, and we sincerely want to thank all who have lent their time to this effort.

For this edition, we especially want to thank Greg DeYong and Jerry Kilty for their help. Greg wrote the questions for each chapter and provided many helpful suggestions. Jerry has spent much time just talking to us about the APICS Certification Exam modules and how the Certification courses work.

A special thanks to Rhonda Lummus for all of the spirited discussion about this book and supply chain management in general. She has been a great inspiration and a shout out to our families for putting up with our absences as we worked on the revisions.

A key person who enabled us to go forward is Robert Argentieri of McGraw-Hill Professional. His patience over many years led to the development of this edition of the book. We are indebted to him and thank him very much for the support.

F. Robert Jacobs
William L. Berry
D. Clay Whybark

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CHAPTER 1

Manufacturing Planning and Control

Manufacturing planning and control (MPC) is concerned with planning and controlling all aspects of manufacturing from managing materials and scheduling machines and people to coordinating suppliers and planning shipments to customers. Because these activities must change over time to respond to different markets and new company strategies, this chapter provides a framework for evaluating these responses as the competitive environment changes.

The development of an effective MPC system is key to the success of any goods-producing company. Moreover, truly effective MPC systems coordinate supply chains—joint efforts across company boundaries. Finally, MPC systems design is not a one-time effort; the systems must continuously adapt to changes in the company environment, strategy, customer requirements, manufacturing problems, and new supply chain opportunities.

The critical question is not what one has accomplished; it is "What should the firm, together with its supply chain partners, do next?" To put these ideas in perspective, this chapter is organized around the following four managerial concerns:

- *The MPC system defined:* What are the typical tasks performed by the MPC system and how do these tasks affect company operations?
- *An MPC system framework:* What are the key MPC system components and how do they respond to a company's needs?
- *Matching the MPC system with the needs of the firm:* How do supply-chain product and process issues affect MPC system design?
- *Evolution of the MPC system:* What forces drive changes in the MPC system and how do companies respond to the forces?

The MPC System Defined

This section explains what the MPC system does and some of the costs and benefits associated with effective MPC systems. The essential task of the MPC system is to manage efficiently the flow of material, to utilize effectively people and equipment, and to respond to customer requirements by using the capacity of the suppliers, that of the internal facilities, and (in some cases) that of the customers to meet customer demand. Important ancillary activities involve the acquisition of information from customers on product needs and providing customers with information on delivery dates and product status. An important principle here is that the MPC system provides the information upon which managers make effective decisions. The MPC system does not make decisions nor manage the operations—managers perform those activities. The MPC system provides the support for them to do so wisely.

Typical MPC Support Activities

The support activities of the MPC system can be broken roughly into three time horizons: long term, medium term, and short term. In the long term, the system is responsible for providing information to make decisions on the appropriate amount of capacity (including equipment, buildings, suppliers, and so forth) to meet the market demands of the future. This is particularly important in that these decisions set the parameters within which the firm responds to current demands and copes with short-term shifts in customer preferences. Moreover, long-term planning is necessary for the firm to provide the appropriate mix of human resource capabilities, technology, and geographical locations to meet the firm's future needs. In the case of supply chain planning, the long term has to include the same kind of capacity planning for the key suppliers. For firms that outsource some of their manufacturing to outside companies, the planning of supplier capacity can be more critical than internal capacity planning. The best choices for outsourcing partners are those that demonstrate their capabilities to ramp up and adjust capacities to the actual dictates of the marketplace.

In the intermediate term, the fundamental issue addressed by the MPC system is matching supply and demand in terms of both volume and product mix. Although this is also true in the longer term, in the intermediate term, the focus is more on providing the exact material and production capacity needed to meet customer needs. This means planning for the right quantities of material to arrive at the right time and place to support product production and distribution. It also means maintaining appropriate levels of raw material, work in process, and finished goods inventories in the correct locations to meet market needs. Another aspect of the intermediate-term tasks is providing customers with information on expected delivery times and communicating to suppliers the correct quantities and delivery times for the material they supply. Planning of capacity may require determining employment levels, overtime possibilities, subcontracting needs, and support requirements. It is often in the intermediate time frame that specific coordinated plans—including corporate budgets, sales plans and quotas, and output objectives—are set. The MPC system has an important role in formulating these plans.

In the short term, detailed scheduling of resources is required to meet production requirements. This involves time, people, material, equipment, and facilities. Key to this activity is working on the right things. As the day-to-day activities continue, the MPC system must track the use of resources and execution results to report on material consumption, labor utilization, equipment utilization, completion of customer orders, and other important measures of manufacturing performance. Moreover, as customers change their minds, things go wrong, and other changes occur, the MPC system must provide the information to managers, customers, and suppliers on what happened; provide problem-solving support; and report on the resolution of the problems. Throughout this process, communication with customers on production status and changes in expectations must be maintained.

To effectively manage the manufacturing processes, a number of manufacturing performance indicators need to be compiled; including equipment and labor utilization, project completions, and the costs associated with departments and products. Also, measures of customer satisfaction such as late deliveries, product returns, quantity errors, and other mistakes are needed. The implications physically and financially of the activities on the manufacturing floor are collected, summarized, and reported through the MPC system.

The initial costs for an MPC system can be substantial. Moreover, the ongoing operational costs are also significant. An effective MPC system requires a large number of professionals and all their supporting resources, including computers, training, maintenance, and space. It is not uncommon to find the largest number of indirect employees at a manufacturing firm to be involved in using the MPC system.

An MPC System Framework

The MPC system is typically embedded in an enterprise resource planning (ERP) system. This facilitates meeting the strategic requirements of the firm by helping to coordinate, as knowledge, technology, and markets change, the MPC activities with those of other areas of the firm. This section outlines the framework for understanding the MPC system.

MPC System Activities

Figure 1.1 provides a framework of the general MPC system that would be used within a firm for planning and controlling its manufacturing operations. In addition, it shows the linkages required to coordinate the MPC activities with the firms in the supply chain. The framework shown in Figure 1.1 is essentially what one will find as a key part of any commercial ERP system. The framework is divided into three parts or phases. The top third, or front end, is the set of activities and systems for overall direction setting. The front end establishes the overall company direction for MPC. Demand management encompasses forecasting customer/end-product demand, entering orders, promising orders, accommodating interplant and intercompany demand, and understanding spare parts requirements. Demand management coordinates all activities of the business that place demands on manufacturing capacity.

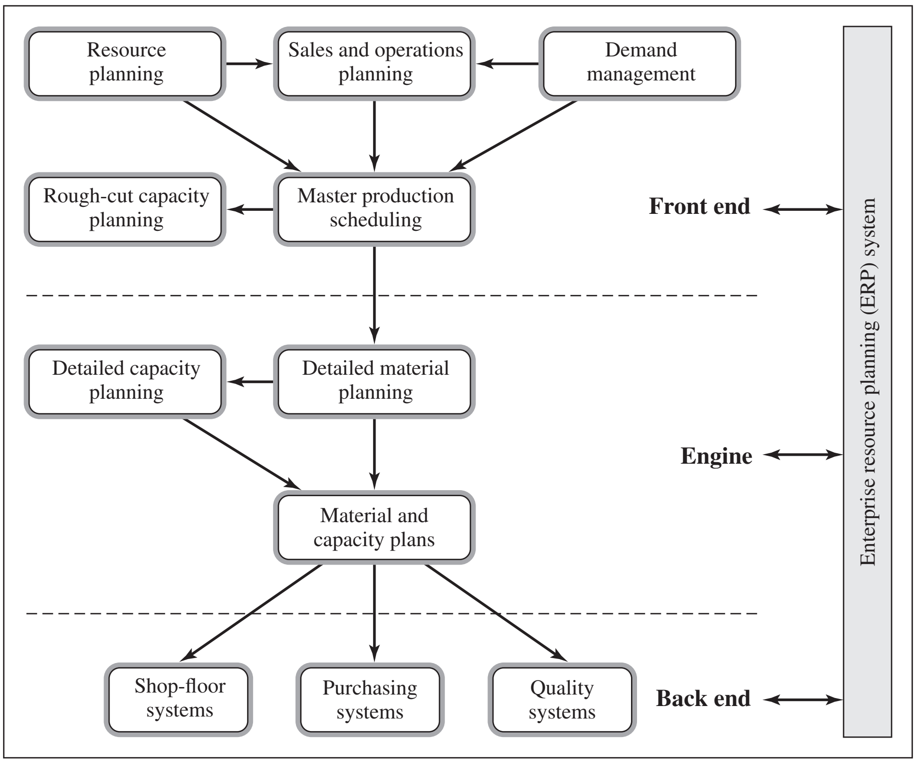

Figure 1.1 Manufacturing Planning and Control System (simplified)

Sales and operations planning (SOP) balances the sales/marketing plans with available production resources. The result is an agreed-on company game plan that ensures that manufacturing can support the company's sales activities and strategy. Increasingly, SOP is receiving more management attention as the need for coordination is recognized in progressive firms. The master production schedule (MPS) is the version of the sales and operations plan that is in manufacturing language. It states which end items or product options manufacturing will build in the future. The MPS must support both sales and operations plans. Resource planning determines the capacity necessary to produce the products required now and in the future. Eventually this means bricks and mortar, while in the short run it means labor and machine hours. Resource planning provides the basis for matching manufacturing plans and capacity.

The middle third, or engine, in Figure 1.1 encompasses the set of MPC systems for detailed material and capacity planning. The MPS feeds directly into the detailed material planning module. Firms with a limited product complexity or range can simply specify rates of production for developing these plans. However, firms producing a wide variety of products with many parts per product require detailed material planning. This can involve calculating requirements for thousands of parts and components. The formal logic for this is called material requirements planning (MRP). It determines (explodes) the period-by-period (time-phased) requirements for all component parts and raw materials needed to produce all the products in the MPS. This material plan can thereafter be utilized in the detailed capacity planning systems to compute the labor and/or machine center capacity required to manufacture all the component parts.

The bottom third, or back end, of Figure 1.1 depicts MPC execution systems. Here, again, the system configuration depends on the products manufactured and production processes employed. For example, firms producing a large variety of products using thousands of parts often group all equipment of a similar type into a single work center. Their shop-floor systems establish priorities for all shop orders at each work center so the orders can be properly sequenced. Other firms will group mixtures of equipment that produce a similar set of parts into work centers called *production cells*. For them, production rates and just-in-time (JIT) systems for execution are appropriate.

The purchasing systems provide detailed part or subsystem information to the company suppliers. In the case of arm's-length relationships with these suppliers, the supplier systems will produce purchase orders that will be transmitted to the suppliers. Thereafter, the company MPC systems should provide suppliers with updated priority information, based on current company conditions—as well as conditions in their customers' companies. In the case of closer (partnership) relations with suppliers, information can also include future plans—to help the suppliers understand expected needs. In a general sense the receiving end of this information is the demand management module of the front end in the suppliers' MPC systems.

In firms using MRP systems, execution of the material and capacity plans involves detailed scheduling of machines and other work centers. This scheduling must reflect such routine events as starting and completing orders for parts and any problem conditions, such as breakdowns or absenteeism. These schedules are often available on a real-time basis from the ERP system database. Real-time data are particularly important in factories with complex manufacturing processes and/or customers demanding responsiveness to volume, design, or delivery schedule changes.

Components and materials sourced from outside the organization require an analogous detailed schedule. This schedule is the basis for the procurement of outside work center capacity. It must also be planned and scheduled well to maximize final customer satisfaction. Best-practice supplier systems typically separate the procurement or contractual activity from routine order release and follow-up. Procurement, a highly professional job, involves contracting for vendor capacity and establishing ground rules for order release and order follow-up. These tasks take on extra dimensions as procurement involves global sourcing and multinational coordination of schedules.

The quality assurance systems monitor product quality and manufacturing process capability. Customer quality requirements are a key input to the quality system. Thus, there should be feedback to the MPC system from customers who discover a quality problem. Similarly, there should be communication with the customer when the quality assurance system uncovers a problem. Monitoring manufacturing process capability is essential to meet the customer's current quality requirements and changes that might be needed in the future. Customer feedback is essential to making changes to the quality systems to meet customer demand.

Some important activities are not depicted in Figure 1.1. These include the measurement, follow-up, and control of actual results. As products are manufactured, the rate of production and timing of specific completion can be compared to plans. As shipments are made to customers, measures of actual customer service can be obtained. As capacity is used, it too can be compared to plans. If actual results differ from plan, appropriate actions to bring the results back to plan or modifications of the plan must be made. These measurements and control actions are part of all three phases of the MPC system.

The three-phase framework for planning and control of manufacturing is supported by widely available MPC systems and software, from master production scheduling to the back-end systems. This software is not only integrated to follow the framework, it is also linked to other business activities in the ERP systems of many firms. That means that the MPC systems provide inputs to the financial, distribution, marketing, and human resources systems that require the information.

Matching the MPC System with the Needs of the Firm

The specific requirements for the MPC system design depend on the nature of the production process, the degree of supply chain integration, customers' expectations, and the needs of management. As the MPC system is required to integrate with other company systems in the supply chain and/or with the ERP system of the firm, additional design parameters are introduced. Moreover, these MPC system requirements are not static. As competitive conditions, customer expectations, supplier capabilities, and internal needs change, the MPC system needs to change.

The MPC system will be changed based on the ongoing goal to meet customer expectations and maximize value to the customer. Customer expectations relate to such competitive priorities as speed of delivery, delivery reliability, and availability from stock. Other customer requests might include cost reductions or flexibility to customize a product. These have a direct impact on how the MPC system is designed and operated.

Internet/cloud based systems are an important way to support intrafirm coordination efforts. Inventories between partners in the supply chain can be replaced by speedier information. Technology changes dramatically affect the way users interact with the MPC system. As information processing capabilities increase, MPC systems evolve to utilize the latest technologies.

The MPC system must also reflect the physical changes taking place on the factory floor. Outsourcing, contract manufacturing, and the subcontracting of corporate functions can all dramatically affect MPC system design. Moves from job shops to flow processes to cellular manufacturing approaches affect the MPC system design as well. Providing accurate information at the level where decisions are made and in appropriate time frames, is essential to coordinating the factory floor and support activities.

It is not, however, just on the factory floor that changes dictate the MPC system needs. As the firm shapes its manufacturing strategy, different modules of the MPC system may need to be modified to respond. As an example, firms that are increasing product variety may need to strengthen the master production scheduling and detailed material planning modules in order to more quickly phase in new products and phase out the old. Firms that are competing on delivery speed may need to improve shop-floor execution and feedback systems to more closely monitor the progress of products through the manufacturing facility. This matching of strategic direction with MPC system design is as dynamic as any of the other elements that shape the MPC system requirements.

An MPC Classification Schema

Figure 1.2 shows the relationship between MPC system approaches, the complexity of the manufactured product as expressed in the number of subparts, and the repetitive nature of production, expressed as the time between successive units. Figure 1.2 also shows some example products that fit these time and complexity scales.

Several MPC approaches presented in Figure 1.2 are appropriate for products that fit in various points in the schema. The figure demonstrates that the MPC emphasis changes as the nature of the product, process, or both, changes. For example, as a product's sales volume grows over time, the MPC emphasis might shift from right to left. Regardless of where the company is in Figure 1.2, it is necessary to perform all the activities depicted in Figure 1.1. However, the ways in which the activities are performed can be quite different for firms at different points in Figure 1.2.

The lower left-hand corner of Figure 1.2 shows a flow-oriented manufacturing process typical of many chemical, food, petroleum, and bulk product firms. Because products are produced in streams instead of discrete batches, virtually no time elapses between successive units. With these processes, the front-end concern of the MPC system is primarily the flow rates that become the MPS. Typically, these products have relatively few component parts, so management of the engine planning systems is straightforward. Depending on how components are purchased, the back end may involve some complexity. Typically, these firms' major cost is for raw materials, although transportation costs can also be significant.

Repetitive manufacturing activities are found in many plants that assemble similar products (e.g., automobiles, watches, personal computers, pharmaceuticals, and televisions). For such products, component-part management is necessary, but everything is coordinated with the flow or assembly rate for the end items.

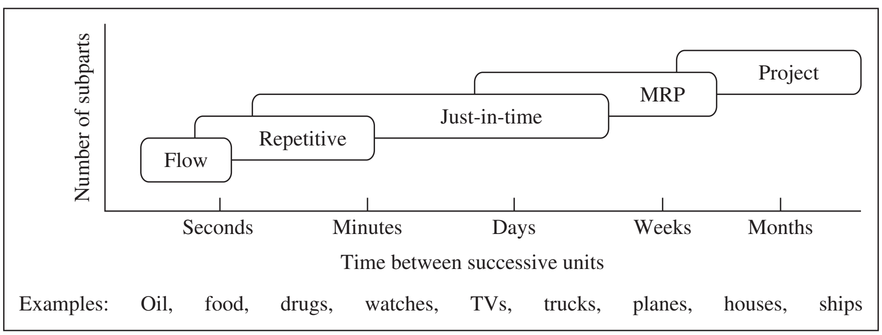

Figure 1.2 MPC Classification Schema

The middle of the figure shows a large application area for just-in-time (JIT) systems. Using lean manufacturing approaches, many firms today try to move their processes from right to left in the figure. That is, they try to make processes more repetitive as opposed to unique in order to achieve the operational advantages of repetitive manufacturing (shorter production cycles, reduced lead times, lower inventories, and the like). JIT is shown as spanning a wide variety of products and processes. This MPC approach is increasingly being integrated with more traditional MRP-based systems. The goal is to achieve better MPC system performance and to reduce costs of maintaining the MPC system.

Figure 1.2 also shows MRP as spanning a wide area. MRP is often the platform for ERP applications and is key to any MPC system involving management of a complicated parts situation. The majority of manufacturing firms have this sort of complexity, and MRP-based systems continue to be widely applied. For many firms, successful use of MRP is an important step in evolving their approaches to MPC. Once routine MRP operation is achieved, portions of the product and processes that can be executed with JIT methodologies can be selected.

The last form of MPC depicted in Figure 1.2, the project type, is applied to unique long-lead-time products, such as ships and highly customized products. Here, the primary concern is usually management of the time dimension. Related to time is cost. Project management attempts to continually assess partially completed projects' status in terms of expected completion dates and costs. Some firms have successfully integrated MRP approaches with the problems of project management. This is particularly effective in planning and controlling the combined activities of engineering and manufacturing.

Evolution of the MPC System

This chapter covers the dynamism of the MPC system. Because this topic is important, an entire section is devoted to it. Although the activities shown in Figure 1.1 are performed in every manufacturing company, whether large or small, MPC system configuration depends strongly on the company's attributes at a particular point in time. The key to keeping the MPC system matched to evolving company needs is to ensure that system activities are synchronized and focused on the firm's strategy. This ensures that detailed MPC decision making is in harmony with the company's game plan. But the process is not static—the need for matching is ongoing.

The Changing Competitive World

Figure 1.3 depicts some manufacturing firms' typical responses to changing marketplace dictates. New technology, products, processes, systems, and techniques permit new competitive initiatives; global competition intensifies many of these forces. Marketplace dictates drive revisions in company strategy, which in turn often call for changes in manufacturing strategy, manufacturing processes, and MPC systems.

Shorter product life cycles come about partly because consumers have access to products from all over the world. This has spawned the move to "time-based competition." Who can get to the market quickest? Similarly, today's market insists on ever-higher quality, which in turn has led to many changes in manufacturing practices. Cost pressures have translated into reductions of all manufacturing cost components from material and labor to overhead and energy.

But increasingly, cost and quality are essential to successfully playing the game—winning requires flexibility and responsiveness in dealing with changing customer demands. Clearly, these pressures and responses require changes in both the MPC system and the underlying manufacturing process. As Figure 1.3 shows, typical MPC responses are MRP and JIT. Process responses include automation, simplification, and production cells for cellular manufacturing.

Reacting to the Changes

If the MPC system has remained unchanged for a significant length of time, it may no longer be appropriate to the company's needs. The system, like the strategy and processes themselves, must change to meet the dictates of the market. In many instances,

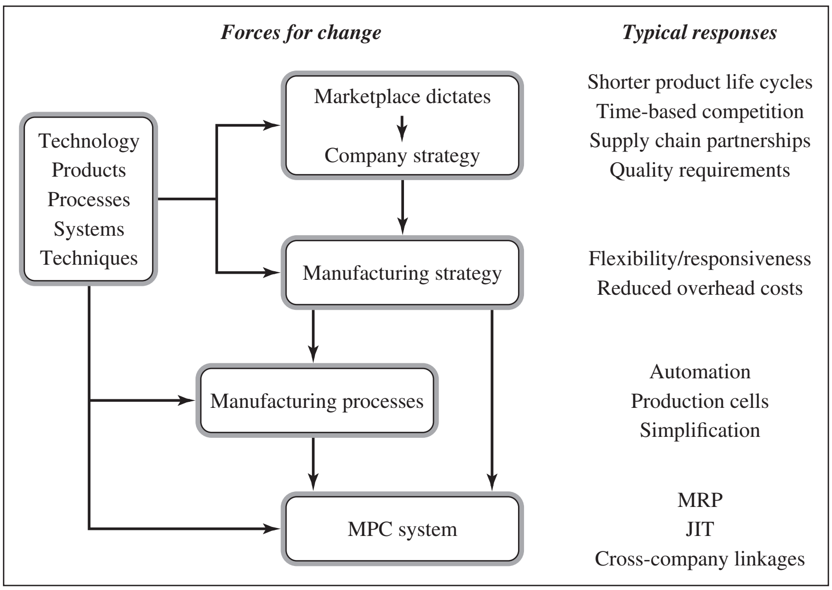

Figure 1.3 Evolutionary Responses to Forces for Change

this may simply imply a different set of evaluative criteria for the MPC system. In other cases, new modules or information may be required. In yet other cases, entire MPC activities may need to be eliminated. For example, JIT systems frequently move materials so quickly through the factory that MRP and shop-floor scheduling systems to track them are not needed. In supply chain management approaches, the emphasis shifts to the total costs (and values created) in the joint activities of more than one firm. The typical focus is on the dyad: two firms where time and inventories are substantially reduced.

The need for evolution in MPC systems implies the need for periodic auditing that compares system responses to the marketplace's requirements. The audit must address not only the system's focus but also the concomitant training of people and match with current objectives. Although the MPC framework in Figure 1.1 is general, its application is specific and evolving. Keeping it on track is an essential feature of MPC itself.

Concluding Principles

This chapter lays the groundwork for the rest of the book. Defining and adjusting the MPC system to support the manufacturing activity are ongoing challenges. In the rest of the book, always ask how the general framework applies in specific instances, and what is happening to ensure a better match between MPC system design and marketplace dictates. Following are the main principles from this chapter:

- The framework for MPC is general, and all three phases must be performed, but specific applications must reflect particular company conditions and objectives.
- In supply chain environments, the MPC system must coordinate the planning and control efforts across all companies involved.
- MPC systems should support the strategy and tactics pursued by the firm in which they are implemented.
- Different manufacturing processes often dictate the need for different designs of the MPC system.
- The MPC system should evolve to meet changing requirements in the market, technology, products, and manufacturing processes.
- The MPC system should be comprehensive in supporting the management of all manufacturing resources.
- An effective MPC system can contribute to competitive performance by lowering costs and providing greater responsiveness to the market.
- In firms that have an integrated ERP system the MPC system should integrate with and support cross-functional planning through the ERP system.

Discussion Questions

1. The discussion of the framework for MPC seems to imply that overall direction setting must be done before detailed material and capacity planning activities can be accomplished. The latter must be done before executing and controlling the plans is possible. Do you agree? Give an example supporting your position.
2. Apply the MPC framework to a college setting; your current job, business, or institution; or one of your friend's settings. In particular, identify the front end, engine, and back end.
3. As changes take place in the world, the MPC system would require modifications to adapt. What changes can you see that will require changes in the MPC system?
4. One of the local company's production managers asked you to advise her on installing an MPC system. She starts by asking you which particular software brand you prefer and if you believe in ERP systems. What questions would you ask her?

APICS/CPIM Certification Questions

1. Manufacturing planning and control (MPC) includes which of the following activities?
   I. Material management
   II. Product marketing
   III. Coordinating suppliers
   a. I only
   b. II only
   c. III only
   d. I and III

2. In the MPC process, capacity decisions (equipment, facilities, suppliers, etc.) are most likely to occur in which time horizon?
   a. Short
   b. Intermediate
   c. Long
   d. Immediate

3. In the MPC process, detailed scheduling decisions are most likely to occur in which time horizon?
   a. Short
   b. Intermediate
   c. Long
   d. Immediate

4. Shop-floor systems are a part of which MPC phase?
   a. Direction setting
   b. Detailed planning
   c. Execution
   d. All of the above
5. Sales and operations planning (SOP) and demand management are a part of which MPC phase?
   a. Direction setting
   b. Detailed planning
   c. Execution
   d. All of the above
6. Master production scheduling (MPS) and resource planning are a part of which MPC phase?
   a. Direction setting
   b. Detailed planning
   c. Execution
   d. All of the above
7. Measurement and control are a part of which MPC phase?
   a. Direction setting
   b. Detailed planning
   c. Execution
   d. All of the above
8. Products that are part of a continuous production process (e.g., petroleum products) would most likely use which form of MPC?
   a. MRP
   b. Just-in-time
   c. Flow
   d. Repetitive
   e. Project
9. Products that are part of a one-time production process (e.g., bridges or aircraft carriers) would most likely use which form of MPC?
   a. Just-in-time
   b. Flow
   c. Repetitive
   d. Project

10. Updating an old MPC system can include which of the following?

I. Adding new modules or functionality
II. Consideration of new decision criteria
III. Removing unneeded/obsolete modules or functionality

a. I only
b. II only
c. III only
d. I, II, and III

CHAPTER 2

Enterprise Resource Planning (ERP)

This chapter describes aspects of the integrated enterprise resource planning (ERP) systems that are now commonly used by large companies to support manufacturing planning and control (MPC) systems. Major software vendors such as SAP, Oracle, and JDA software offer state-of-the art software designed to provide real-time data to support better routine decision making, improve the efficiency of transaction processing, foster cross-functional integration, and provide improved insights into how the business should be run. This chapter is organized around four major topics:

- *What ERP is:* What is the scope of ERP implementations and how are the various modules of the software organized?
- *How ERP connects the organizational units:* That is, how does ERP help integrate overall company operations?
- *How MPC decisions are supported by ERP:* What are the detailed MPC issues addressed by ERP and how does an ERP system help address these issues?
- *Performance metrics to evaluate integrated system effectiveness:* How do overall metrics put an end to "functional silo" thinking?

In most companies, ERP provides the information backbone needed to manage day-to-day execution. Many of the standard production planning and control functions are supported by ERP. For MPC activities, this means supporting activities from the front end, through the engine, to the back end. In particular, standard applications include demand management, forecasting sales and operations planning, master production scheduling, material requirements planning, production activity control, and inventory control. The ERP software is often extended through either commercial software designed to work with the ERP system or through custom programmed modules built with spreadsheets and other general purpose software.

What Is ERP?

The term *enterprise resource planning* (ERP) can cover different things, depending on the viewpoint. From the view of managers in a company, the emphasis is on the word *planning;* ERP represents a comprehensive software approach to support decisions concurrent with planning and controlling the business. On the other hand, for the information technology community, ERP is a term to describe a software system that integrates application programs in finance, manufacturing, supply chain management, sales and marketing, human resources, and the other functions in a firm. This integration is accomplished through a database shared by all the functions and data-processing applications in the firm. ERP systems typically are very efficient at handling the many transactions that document the activities of a company. The chapter begins by describing what ERP should accomplish for management, with an emphasis on planning. Following this, the chapter examines the design of ERP software programs and provides points to consider in choosing an ERP system. The chapter focuses on how ERP software supports MPC systems.

ERP systems allow for integrated planning across a firm's functional areas, such as finance, marketing, and human resources. Perhaps more importantly, ERP also supports integrated *execution* across functional areas. As supply chain management becomes more important, the focus moves to coordinated planning and execution across companies. In many cases this work is supported by ERP systems.

Consistent Numbers

ERP requires a company to have consistent definitions across functional areas. Consider the problem of measuring sales. When is a sale recognized? Is it when the salesperson gets a "yes" from the customer? When the order arrives at the company? When manufacturing on the order begins? Is it when manufacturing completes an order? When items are picked from finished goods? When they physically leave the premises? When they are invoiced? When they arrive at the customer site? What is needed is a set of agreed-on definitions that are used by all functional units when they are processing their transactions. Consistent definitions of such measures as demand, stockouts, raw materials inventory, and finished goods inventory, for example, can then be made. This consistency is a basic building block for ERP systems.

ERP, with the emphasis on planning, is designed to allow much tighter integration, thus eliminating the problem of local optimization. Companies implementing ERP also strive to derive benefits through much greater efficiency gained by an integrated MPC process. In addition, better responsiveness to the needs of customers is obtained through the real-time information provided by the ERP system. The next sections describe elements of ERP software.

Software Imperatives

Four aspects of ERP software determine the quality of an ERP system:

1. The software should be **multifunctional in scope** with the ability to track financial results in monetary terms, procurement activity in units of material, sales in terms of product units and services, and manufacturing or conversion processes in units of resources or people. That is, excellent ERP software produces results closely related to the needs of people for their day-to-day work.
2. The software should be **integrated.** Thus, when a transaction or data representing an activity of the business is entered by one of the functions, data regarding the other related functions are changed as well. This eliminates the need for reposting data to the system. Integration also ensures a common vision—everyone sings from the same sheet of music.
3. The software needs to be **modular** in structure so it can be combined into a single expansive system, narrowly focused on a single function, or connected with software from another function or application.
4. The software must **facilitate classic MPC activities,** including forecasting, production planning, shop-floor systems, and inventory management.

An ERP system is most appropriate for a company seeking the benefits of data and process integration supported by its information system. Benefit is gained from the elimination of redundant clerical processes, increased accuracy in information, superior computational processes, and improved speed in responding to customer requirements.

An ERP software system can be built with software modules from different vendors, or it can be purchased from a single vendor. A multivendor approach can provide the opportunity to purchase “best in class” of each module. But this is usually at the expense of increased cost and greater resources needed to implement and integrate the functional modules. On the other hand, a single-vendor approach may be easier to implement, but the features and functionality may not be the best available.

Routine Decision Making

It is important to make a distinction between the transaction processing capability and the decision support capability of an ERP system. **Transaction processing** relates to the posting and tracking of the activities that document the business. When an item is purchased from a vendor, for example, a specific sequence of activities occurs. The solicitation of the offer, acceptance of the offer, delivery of goods, storage in inventory, and payment for the purchase are all activities that occur as a result of the purchase. The efficient handling of the transactions as goods move through each step of the production process is the primary goal of an ERP system.

A second objective of an ERP system is decision support. **Decision support** relates to how well the system helps the user make intelligent judgments about how to run the business. A key point here is that *people,* not software, make the decisions. The system *supports* better decision making. In the case of MPC, for example, decisions must be made concerning the amount to purchase, the selection of the vendor, and how items should be delivered. These decisions are made by MPC professionals while ERP systems are oriented toward transaction processing. But over time, they evolve using decision logic based on parameters set in the system. For example, for items stored in inventory, the specific reorder points, order quantities, vendors, transportation vendors, and storage locations can be established when the items are initially entered in the system. At a later point, the decision logic can be revisited to improve the results. A major industry has been built around the development of supplementary software packages designed to provide more intelligent decision support to ERP systems.

Choosing ERP Software

Key considerations when evaluating ERP software are:

1. The ability of the software to support the needs of the MPC professionals and all other functional units' professionals.
2. The complexity of the business, size of the business, degree of vertical integration, and level of international operations.
3. The scope of functionality needed—is decision making reasonably routine, or is complex optimization required?
4. The differences in the conversion processes. Is discrete manufacturing used, or process manufacturing, or both? The needs of these entities are different and perhaps difficult to accommodate with a single system.
5. The degree of sophistication and unique requirements of the firm's processes. Are there unique customer information requirements? How much of a custom solution is needed?
6. The alignment of the MPC modules with the needs of the firm. For example, are the mechanisms for aggregating demand for forecasting purposes adequate? Can the inventory control module accommodate the requirement to uniquely identify production batches?
7. Will implementing the system be disruptive? Are radical process changes needed?
8. The computer hardware and networking availability. Is the existing infrastructure compatible? How is this changing in the future? Where is the industry going? Does the system need to be state of the art?

How ERP Connects the Functional Units

A typical ERP system is made up of functionally oriented and tightly integrated modules. All the modules of the system use a common database that is updated in real time. Each module has the same user interface, similar to that of the familiar Microsoft Office products, thus making the use of the different modules much easier for users trained on the system. ERP systems from various vendors are organized in different ways, but typically modules are focused on at least the following four functional areas: finance, manufacturing and supply chain management, sales and marketing, and human resources.

Figure 2.1 depicts the scope of ERP applications. The diagram is meant to show how a comprehensive information system uses ERP as the backbone of the information system. Many other software-based applications may be integrated with the ERP system but are not necessarily included in the ERP system. The use of more specialized software such as decision support systems can often bring significant competitive advantage to a firm. The following brief descriptions of typical module functionality give an indication of how comprehensive the applications can be.

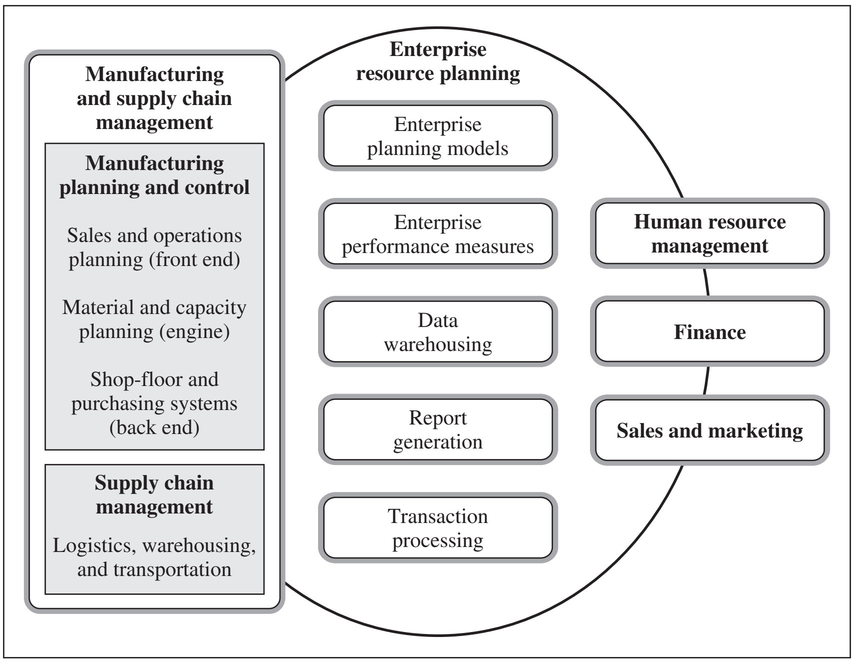

Figure 2.1 The Scope of ERP Applications

Finance

As a company grows through acquisition, and as business units make more of their own decisions, many companies find themselves with incompatible and sometimes conflicting financial data. An ERP system provides a common platform for financial data capture, a common set of numbers, and processes, facilitating rapid reconciliation of the general ledger. The real value of an ERP system is in the automatic capture of basic accounting transactions from the source of the transactions. The actual order from a customer, for example, is used not only by manufacturing to trigger production requirements, but also becomes the information for the update of accounts payable when the order is actually shipped.

Manufacturing and Supply Chain Management

This set of applications is the largest and most complex of the module categories. The MPC system components discussed in this book (front end, engine, and back end) are concentrated in this area. Typical components include:

- *Sales and operations planning* coordinates the various planning efforts including marketing planning, financial planning, operations planning, and human resource planning.
- *Materials management* covers tasks within the supply chain, including purchasing, vendor evaluation, and invoice management. It also includes inventory and warehouse management functions to support the efficient control of materials.
- *Plant maintenance* supports the activities associated with planning and performing repairs and preventive maintenance.
- *Quality system* software implements procedures for quality control and assurance.
- *Production planning and control* supports both discrete and process manufacturing. Repetitive and configure-to-order approaches are typically provided. Most ERP systems address all phases of manufacturing, including capacity leveling, material requirements planning, just-in-time (JIT), product costing, bill of materials processing, and database maintenance. Orders can be generated from sales orders or from links to the Internet or the Cloud.
- *Project management* systems facilitate the setup, management, and evaluation of large, complex projects.

Supply Chain Management

There are a number of applications that are devoted to supporting supply chain management. They are found in departments such as manufacturing, logistics, materials management, sales and marketing. They are designed to support activities like distribution, warehousing, shipping, transportation, and coordination of supply chain members. The increasingly international nature of these activities means that managing them requires global support. Thus these applications are often configured to handle trans-border transactions. For instance, the warehousing of a shipment of components coming into Germany from Singapore might require significant labor, transportation, and specialized equipment. Information on the volume, weight, and other characteristics would be needed to plan for these resources. Moreover, they would need to be converted into the resources required.

Sales and Marketing

This group of applications supports customer management; sales order management; forecasting, delivery management, credit checking, configuration management; export controls, customs management; and billing, invoicing, and rebate processing. These modules, like the others, are increasingly implemented globally, allowing firms to manage the sales process worldwide. For example, if an order is received in Hong Kong, but the products are not available locally, they may be internally procured from warehouses in other parts of the world and shipped to arrive together at the Hong Kong customer's site.

Human Resources

This set of applications supports the capabilities needed to manage, schedule, pay, hire, and train the people who make the organization run. Typical functions include payroll, benefits administration, applicant data administration, personnel development planning, workforce planning, schedule and shift planning, time management, and travel expense accounting.

Customized Software

In addition to the standard application modules, many companies utilize special add-on modules that link to the standard modules, thus tailoring applications to specific needs. These modules may be tailored to specific industries such as large-scale assembly, batch manufacturing, make-to-order, chemical/petrochemical, oil and gas, hospital, and banking. They may also provide special decision support functions such as optimal scheduling of critical resources.

Even though the scope of applications included in standard ERP packages is very large, it is usually the case that additional software will be required because of the unique characteristics of each company. A company generates its own unique mix of products and services that are designed to provide a significant competitive advantage to the firm. This unique mix of products and services will need to be supported by unique software capability, some of which may be purchased from vendors and others that will need to be custom designed. Customized software applications are also widely used to coordinate the activities of a firm with its supply chain customers and suppliers.

Data Integration

The software modules, as described earlier, form the core of an ERP system. This core is designed to process the business transactions to support the essential activities of an enterprise in an efficient manner. Working from a single database, transactions document the activities of the processes used by the enterprise to conduct business. A major value of the integrated database is that information is not reentered at each step of a process, thus reducing errors and reducing work.

Transactions are processed in **real time,** meaning that as soon as the transaction is entered into the system, the effect on items such as inventory status, order status, and accounts receivable is known to all users of the system. There is no delay in the processing of a transaction in a real-time system. A customer could, for example, call into an order desk to learn the exact status of an order—or determine the status independently through an Internet connection. From a decision analysis viewpoint, the amount of detail available in the system is extremely rich. If, for example, there was a need to determine the typical lead time for a product produced to order, an analyst could process an information request that selects all of the orders for the product over the past three months, then calculate the time between the order date and delivery date for each order, and, finally, average this time for the whole set of orders. Analyses, such as this lead time example, can be valuable for evaluating improvements designed to make the process more responsive, for example.

To facilitate queries not built into the standard ERP system software, a separate **data warehouse** is commonly employed. A data warehouse is a special program (often running on a totally separate computer) that is designed to automatically capture and process data for uses that are outside the basic ERP system applications. For example, the data warehouse could, on an ongoing basis, capture the data and perform the calculations needed for the typical lead time. The data warehouse software and database is set up so that users may access and analyze data without placing a burden on the operational ERP system. This is a powerful mechanism to support higher-level decision support applications.

A good example of a company making use of a data warehouse is Walmart. Walmart is now able to put two full years of retail store sales data online. Once the definitions of data are made common between the companies, the data can be used by both internal Walmart buyers and outside vendors. The data include sales and current inventory data on products sold at Walmart and Sam's Club stores. Vendors, who are restricted to viewing products they supply, use a Web-based extranet site to collaborate with Walmart's buyers in managing inventory and making replenishment decisions. Vendors' store-by-store sales results for a given day are available to vendors by 4 a.m. the following day. The database exceeds 130 terabytes in size. Each terabyte is the equivalent of 250 million pages of text. At an average of 500 pages per book, a terabyte is a half million books. For Walmart as a whole, that is about 20 major university libraries.

How Manufacturing Planning and Control (MPC) Fits within ERP

MPC is concerned with planning and controlling all aspects of manufacturing, including managing materials, scheduling machines and people, and coordinating suppliers and key customers. The coordination required for success runs across all functional units in the firm. Consider the following simple example to illustrate the degree of coordination required.

Simplified Example

The Ajax Food Services Company has one plant that makes sandwiches. These are sold in vending machines, cafeterias, and small stores. One of the sandwiches is peanut butter and jelly (PBJ). It is made from bread, butter, peanut butter, and grape jelly. When complete, it is wrapped in a standard plastic package used for all Ajax sandwiches. One loaf of bread makes 10 sandwiches, a package of butter makes 50 sandwiches, and containers of peanut butter and jelly each make 20 sandwiches.

Consider the information needed by Ajax for MPC. First Ajax needs to know what demand to expect for its PBJ sandwich in the future. This might be forecast by analyzing detailed sales data from each location where the sandwiches are sold. Because sales are all handled by sales representatives who travel between the various customers, data based on the actual orders and sales reports provided by the sales representatives can be used to make this forecast. The same data are used by human resources to calculate commissions owed to the reps for payroll purposes. Marketing uses the same data to analyze each current location and evaluate the attractiveness of new locations.

Freshness is very important to Ajax, so daily demand forecasts are developed to plan manufacturing. Consider, for example, that Ajax plans to make 300 PBJ sandwiches to be delivered to the customers this Friday. Ajax will actually assemble the sandwiches on Thursday. According to the usage data given earlier, this requires 30 loaves of bread, 6 packages of butter, and 15 containers each of peanut butter and jelly. Freshness is largely dictated by the age of the bread, so it is important that Ajax works closely with the local baker because the baker delivers bread each morning on the basis of the day's assembly schedule. Similarly, the delivery schedules for the butter, peanut butter, and jelly need to be coordinated with the vendors of these items.

Ajax uses college students who work on a part-time basis to assemble the sandwiches. Manufacturing knows that a student can make 60 sandwiches per hour and that sandwiches must be ready for loading into the delivery trucks by 4:00 p.m. on the day prior to delivery. The 300 sandwiches require five hours of work, so the student doing this job needs to start at or before 11:00 a.m. on Thursday to make the sandwiches on time.

An ERP system is designed to provide the information and decision support needed to coordinate this type of activity. Of course, with this simplified example, the coordination is trivial, but consider if the company were making hundreds of different types of sandwiches in 1,000 cities around the world, and these sandwiches were sold at hundreds of sites in each of these cities. This is exactly the scale of operations that can be handled by a modern ERP system.

Precisely how all of these calculations are made is, of course, the main focus of this book. All of the details for how material requirements are calculated, how capacity is planned, and how demand forecasts are made, for example, are explained here in great detail.

Performance Metrics to Evaluate Integrated System Effectiveness

As indicated, one significant advantage that a firm gains from using an integrated ERP system is the ability to obtain current data on how the firm is performing. An ERP system can provide the data needed for a comprehensive set of performance measures to evaluate strategic alignment of the various functions with the firm's strategy. An example of the comprehensiveness of the measures is tracking the time from spending cash on purchases until the cash is received in sales.

The balance sheet and the income and expense statements contain financial measures, such as net profit, that traditionally have been used to evaluate the success of the firm. A limitation of traditional financial metrics is that they primarily tell the story of past events. They are less helpful to guide decision makers in creating future value through investments in customer and supplier relations, employees, manufacturing processes, and other innovations.

Companies use ERP to achieve an integrated, more holistic approach to management of the firm. Figure 2.2 depicts four functional areas that make up the internal supply chain of a manufacturing enterprise: purchasing, manufacturing, sales and distribution, and supply chain management. Tight cooperation is required among these functions for effective MPC. Considered independently, purchasing is mainly concerned with minimizing materials

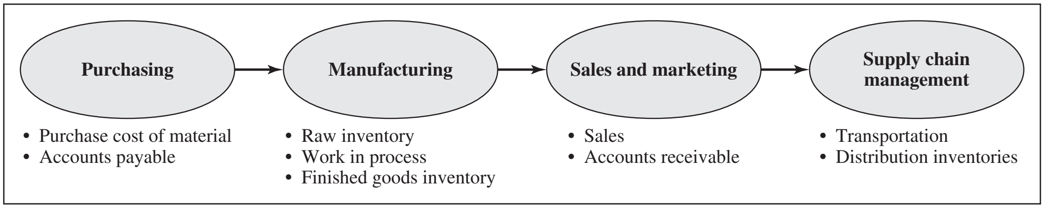

Figure 2.2 Operating Cycle for a Manufacturing Firm

cost, manufacturing with minimum production costs, sales with selling the greatest amount, and supply chain management with minimum distribution and transportation costs. The next section describes how each independently operating function might seek to optimize its operation.

The "Functional Silo" Approach

The purchasing function is responsible for buying all of the material required to support manufacturing operations. When operating independently, this function wishes to know what materials and quantities are going to be needed over the long term. The purchasing group then solicits bids for the best price for each material. The main criterion is simply the cost of the material, and the purchasing function is *evaluated* on this criterion: what is current actual cost versus standard cost? Of course, quality is always going to be important to the group, so typically some type of quality specification will need to be guaranteed by the supplier. But quality is more of a constraint than a goal; suppliers must achieve some minimal level of quality specification. Considerations of delivery schedules, quantities, and responsiveness are also important, but again these considerations are often secondary at best in how the purchasing function is evaluated in a traditional firm.

For manufacturing, making the product at the lowest possible cost is the classic metric. To do this requires minimum equipment downtime, with high equipment and labor utilization. Stopping to set up equipment is not the desire of this group. They are focused on high-volume output, with minimum changeovers. Quality is again "important"—but as in purchasing it is more of a minimum hurdle. Large batches foster better quality performance, because defects often occur during changeovers. Once production reaches some steady state, it is easier to maintain a quality standard.

Long production runs lead to lower unit costs, but they also generate larger inventories. For sales, larger inventories appear at first to be desirable, because these should support customer service. Alas, it is not so; a one-year supply of product A is of no help when the company is out of product B. In addition, in order to maximize sales or meet quotas, sales may promise product variations that can not be made, terms that can not be met, or quantities that require overtime or special processes. Such demands on the firm can lead to reduced quality, excessive costs, and internal stress can lead to a degradation in capability to compete effectively. Thus, pressure for "sales at any cost" can lead to worse customer service due to frustrated expectations on the part of the customers.

Supply chain management can be equally focused but suboptimal. In the classic case its job is moving the product from the manufacturing site to the customer at the lowest possible cost. Depending on the product, it may need to be stored in one or more distribution centers and be moved via one or more different modes of transportation (truck, rail, etc.). Evaluation of supply chain management activities tends to focus on the specific distribution activity involved. For example, many firms focus on the lowest price quotation for moving a product from one stage of the distribution chain to another, rather than on the *total* costs of moving materials *into* and *out of* the overall chain. And even here this cost focus needs to be integrated with other objectives such as lower inventories, faster response times, and better customer service.

Consider the implications if all four areas are allowed to work independently. To take advantage of discounts, purchasing will buy the largest quantities possible. This results in large amounts of raw material inventory. The manufacturing group desires to maximize production volumes in order to spread the significant fixed costs of production over as many units as possible. These large lot sizes result in high amounts of work-in-process inventory, with large quantities of goods pushed into finished goods whether they are needed or not. Large lot sizes also mean that the time between batches increases; therefore, response times to unexpected demand increase. Given the opportunity, the sales group might even sell product that cannot possibly be delivered on time. After all, they are evaluated on sales, not deliveries. Finally, supply chain management will try to fully load every truck that is used to move material to minimize transportation cost. Of course, this may result in large amounts of inventory in distribution centers (perhaps the wrong ones) and might not match well with what customers really need. A more coordinated approach is facilitated by the use of an ERP system. The following is an example of a consistent set of metrics useful for managing supply chain activities effectively.

Integrated Supply Chain Metrics

APICS, a professional organization devoted to improving supply chain management, has developed many metrics to measure the performance of the overall supply chain. It has used these standardized measures to develop benchmarks for comparisons between companies. Figure 2.3 contains a list of some of these measures for typical large industrial products, showing average and best-in-class benchmarks. Similar sets of measures have been developed for many different categories of companies.

Figure 2.3 Typical Supply Chain Metrics

Measure	Description	Best in Class	Average or Medium
Delivery performance	What percentage of orders is shipped according to schedule?	93%	69%
Fill rate by line item	Orders often contain multiple line items. This is the percentage of the actual line items filled.	97%	88%
Perfect order fulfillment	This measures how many complete orders were filled and shipped on time.	92.4%	65.7%
Order fulfillment lead time	The time from when an order is placed to when it is received by the customer.	135 days	225 days
Warranty cost of % of revenue	This is the actual warranty expense divided by revenue.	1.2%	2.4%
Inventory days of supply	This is how long the firm could continue to operate if all sources of supply were cut off.	55 days	84 days
Cash-to-cash cycle time	Considering accounts payable, accounts receivable, and inventory, this is the amount of time it takes to turn cash used to purchase materials into cash from a customer.	35.6 days	99.4 days
Asset turns	This is a measure of how many times the same assets can be used to generate revenue and profit.	4.7 turns	1.7 turns

Source: Ad hoc APICS conference presentation.

A particularly useful approach to measuring performance captures more than the integrated impact that the functions shown in Figure 2.2 have on the entire business supply chain. The best metrics also integrate the other functions. In finance, for example, a metric that measures the relative efficiency of the operating cycle is **cash-to-cash cycle time.** Cash-to-cash cycle time integrates the purchasing, manufacturing, sales and marketing, and supply chain management functions depicted in Figure 2.2. But it also relates well to the financial maxim: cash is king! Calculating the measure requires the use of accounting data related to purchasing, manufacturing, sales and marketing, and supply chain management.

Understanding how cash flows through a business is critical to managing the business effectively. Accountants use the term *operating cycle* to describe the length of time that it takes a business to convert cash outflows for raw materials, labor, and so on, into cash inflows. This cycle time determines, to a large extent, the amount of capital needed to start and operate a business. Conceptually, cash-to-cash cycle time is calculated as follows:

$$\text{Cash-to-cash cycle time} = \text{Inventory days of supply} + \text{Days of sales outstanding} - \text{Average payment period for material} \quad (2.1)$$

The overall result is the number of days between paying for raw materials and getting paid for the product. Going through the details of calculating cash-to-cash cycle time demonstrates the power of integrated information. These calculations are straightforward in an ERP system. The calculation can be divided into three parts: the accounts receivable cycle, the inventory cycle, and the accounts payable cycle.

Figure 2.4 shows the data that are used for calculating cash-to-cash cycle time. The data are controlled by different functions within the company. The current accounts payable amount, an account that is dependent on the credit terms that purchasing negotiates with suppliers, gives the current money that that firm owes its suppliers. As will be seen in the calculation, this is a form of credit to the company.

The inventory account gives the value of the entire inventory within the company. This includes raw materials, work in process, finished goods, and distribution inventory. The value of inventory depends on the quantities stored and also the cost of the inventory to

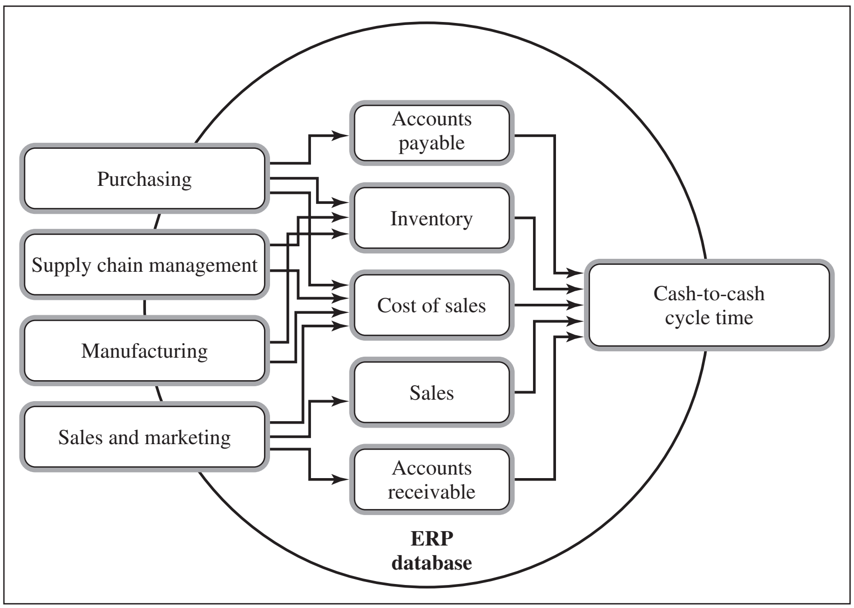

Figure 2.4 Integrated ERP Data for Cash-to-Cash Cycle Time Calculation

the firm. All four functional areas affect the inventory account. Purchasing has the major influence on raw materials. Manufacturing largely determines work in process and finished goods. Sales/distribution influences location of finished goods—as well as amounts through their forecasts and orders.

Just as inventory is affected by all these functions, the cost of sales is dependent on costs that are incurred throughout the firm. For the purposes of the cash-to-cash cycle time calculation, this is expressed as a percentage of total sales. This percentage depends on such items as material cost, labor cost, and all other direct costs associated with the procurement of materials, manufacturing process, and distribution of the product.

Sales are the total sales revenue over a given period of time. Finally, accounts receivable is the amount owed the firm by its customers. The accounts receivable amount will depend on the firm's credit policy and its ability to deliver product in a timely manner. Figure 2.4 shows how the four functional areas influence the cash-to-cash cycle calculation.

Calculating the Cash-to-Cash Time

As noted, the first task in determining the cash-to-cash cycle time is to calculate accounts receivable cycle time. This measures the length of time it takes a business to convert a sale into cash. In other words, how long does it take a business to collect the money owed for goods already sold? One way is to calculate the number of days of sales invested in accounts receivable:

$$S_d = \frac{S}{d} \tag{2.2}$$

where

S_d = average daily sales

S = sales over d days

$$\text{AR}_d = \frac{\text{AR}}{S_d} \tag{2.3}$$

where

AR_d = average days of accounts receivable (the accounts receivable cycle time)

AR = accounts receivable

The next part of the calculation is the inventory cycle time. This is the number of days of inventory measured relative to the cost of sales:

$$C_d = S_d\text{CS} \tag{2.4}$$

where

C_d = average daily cost of sales

CS = cost of sales (percent)

$$I_d = \frac{I}{C_d} \tag{2.5}$$

where

I_d = average days of inventory (the inventory cycle time)

I = current value of inventory (total)

Next, the accounts payable cycle time measures the level of accounts payable relative to the cost of sales:

$$AP_d = \frac{AP}{C_d} \tag{2.6}$$

where

AP_d = average days of accounts payable (the accounts payable cycle time)

AP = accounts payable

Finally, the cash-to-cash cycle time is calculated from the three cycle times.

$$\text{Cash-to-cash cycle time} = AR_d + I_d - AP_d \tag{2.7}$$

Figure 2.5 shows an example of the cash-to-cash cycle time calculation.

Data: Sales over last 30 days = $1,020,000
Accounts receivable at the end of the month = $200,000
Inventory value at the end of the month = $400,000
Cost of sales = 60% of total sales
Accounts payable at the end of the month = $160,000

$$S_d = \frac{S}{d} = \frac{1{,}020{,}000}{30} = 34{,}000$$

$$AR_d = \frac{AR}{S_d} = \frac{200{,}000}{34{,}000} = 5.88 \text{ days}$$

$$C_d = S_d CS = 34{,}000(0.6) = 20{,}400$$

$$I_d = \frac{I}{C_d} = \frac{400{,}000}{20{,}400} = 19.6 \text{ days}$$

$$AP_d = \frac{AP}{C_d} = \frac{160{,}000}{20{,}400} = 7.84 \text{ days}$$

Cash-to-cash cycle time = $AR_d + I_d - AP_d$ = 5.88 + 19.6 – 7.84 = 17.64 days

Figure 2.5 Example of Cash-to-Cash Cycle Time Calculation

The cash-to-cash cycle time is a useful measure for evaluating the relative operating cycle effectiveness of a firm. Some firms are actually able to run a negative value for the measure. This implies the ability to invest in the business as needed—with no requirement for additional funds! Metrics, such as cash-to-cash cycle time, can be efficiently calculated and reported using ERP data. These metrics can even be reported in real time if needed.

Concluding Principles

The value of ERP to a company depends to a great extent on the potential savings that can be derived from the ability to develop common definitions and centralize information and decision making. In terms of supporting the MPC system, it depends on how much value the ERP system can provide to the MPC professionals. For instance, are the supported activities and systems in each of the three phases (the front end, engine, and back end) the ones needed? Can the information be reported in formats useful to the professionals? It is also important to recognize that the value of the system is derived from the synergies obtained from quick access to information from multiple functions in the company. ERP is especially valuable when these functions are located at many different sites within a country or around the world.

The following principles outline how an ERP system can add value by supporting the MPC system.

- ▲ The ERP system must meet the needs of the MPC professionals.
- ▲ The design and performance metrics for the ERP system must reflect the strategy, processes, and customer needs of the firm.
- ▲ All functions that are involved in MPC activities should be part of the ERP system.
- ▲ To achieve efficiencies, data should be captured at the initial entry.
- ▲ There must be a common definition of the data within the company and between companies for successful integration.

Discussion Questions

1. What are the essential attributes of ERP systems?
2. Access the Web sites for the following companies: SAP (www.sap.com), Oracle (www.oracle.com), and JDA software (jda.com). Compare the product offerings of these leading ERP software vendors.
3. What questions would you ask a software vendor to learn about the vendor's system's ability to support your MPC system needs?
4. What is the value of real-time data?

Problems

1. The following data were obtained from a recent quarterly report for an actual company (in millions):

Net revenue	$8,028
Cost of revenue	$6,580
Inventories:	
Production materials	$126
Work-in-process and finished goods	$224
Accounts receivable	$2,689
Accounts payable	$4,326

   Calculate the cash-to-cash cycle time for the company.

2. Evaluate the effect of the following changes that a company makes on cash-to-cash cycle time. Indicate simply the direction of movement of the measurement (i.e., up, down, or no change).

   Reduction in cost-of-goods sold
   More frequent deliveries from suppliers
   Reductions in time customers are allowed to pay for goods
   Change from paying suppliers on receipt of goods to waiting 60 days to pay suppliers
   Write-off of obsolete inventory
   Reduction in labor content in a production process
   Outsourcing the production of a major product

3. Return to the Ajax sandwich example on page 23. Suppose that in addition to the 300 peanut butter and jelly sandwiches to be delivered on Friday, Ajax also needs to make 2,000 sandwiches of other varieties. Assume that the same amount of time is needed to assemble sandwiches and that each parttime student can work for five hours. How many students are needed on Thursday?

4. If the average selling price per sandwich is $2.00 and the cost of materials and labor is $1.25, what is the daily profit if Ajax sells 2,100 sandwiches (unsold sandwiches are discarded at the end of the day)? What if it is a really bad day and Ajax sells only 1,500?

5. Suppose a new bread supplier provides bread that increases the shelf life for sandwiches from one day to two. What does this imply for the calculations in problem 4? What kind of MPC system linkages would be required from Ajax to its customers?